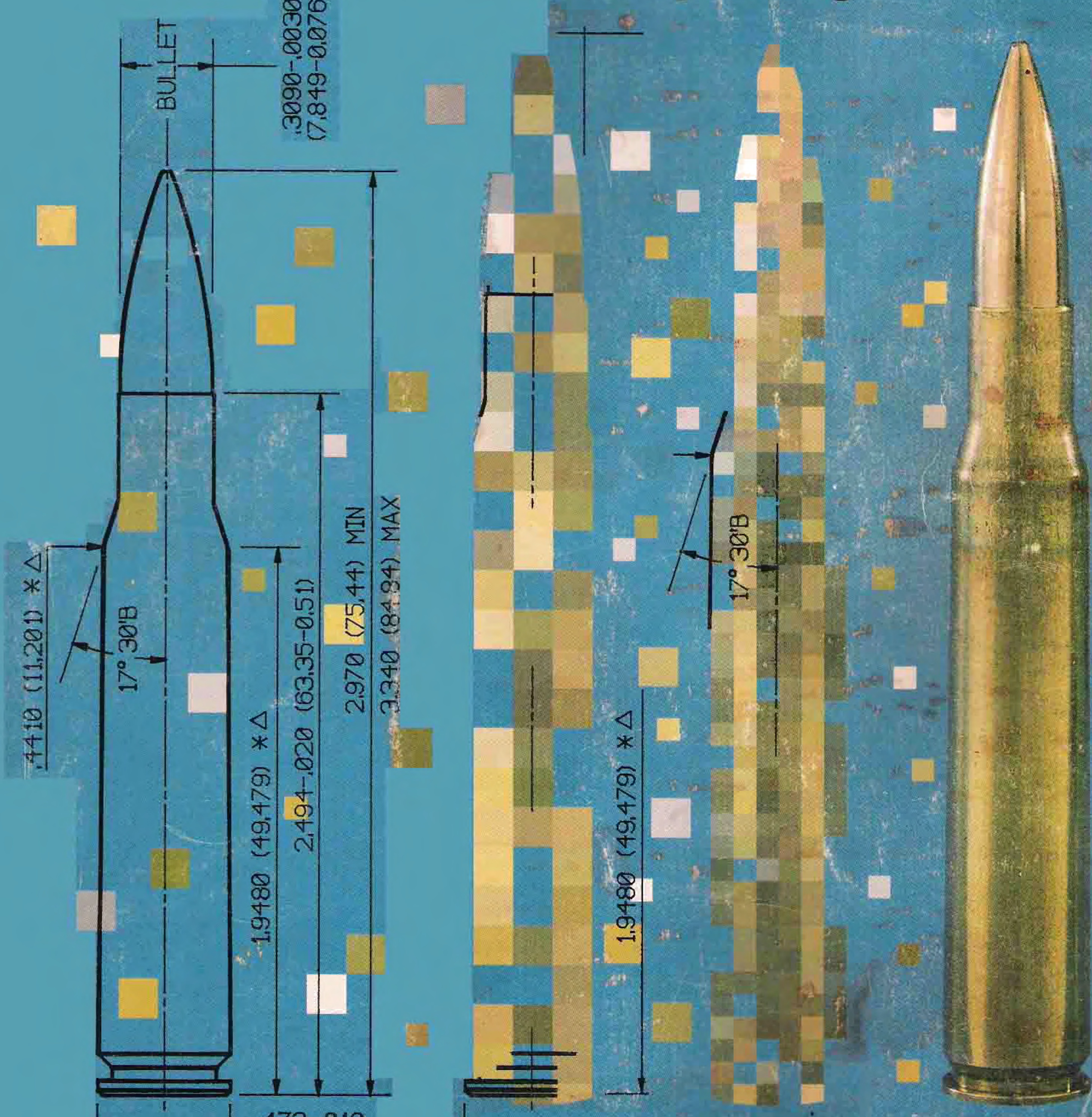
AMMUNITION MAKING

By George E. Frost



A Publication of
the National Rifle Association of America

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An Insider's Story

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George Ernest Frost has been known as "Jack" to his friends in the ammunition industry for nearly six decades—since the day in 1935 when he went to work for the Western Cartridge Co. of East Alton, Illinois. A graduate of Iowa State University, with a Bachelor of Science degree in Chemical Engineering, Frost joined the Western staff to pursue a company sponsored project involving dynamite filler, and stayed for a 27-year career that saw him fill managerial and executive positions in the sales, product services, quality control and military liaison divisions of Western and its parent company, Olin-Mathieson Chemical Corp. While a part of the Olin team, Frost gained a reputation as a top-notch, competitive rifleman and shotgunner, and an avid hunter and outdoorsman.

In 1962, he moved to Lewiston, Idaho, to become Vice President for Production of Cascade Cartridge Co., where he established ammunition manufacturing facilities in Lewiston and a subsidiary plant in San Luis Potosi, Mexico. From Mexico, Frost moved to the Republic of the Philippines and to the position of Executive Vice President and General Manager for The Squires-Bingham Manufacturing Co. He was instrumental in the establishment of facilities for the production of both military and sporting metallic cartridges and shotshells.

Retired since 1979, Frost continues to work with Squires Bingham's successor, Arms Corporation of the Philippines (ARMSCOR), as a consultant. His most recent undertaking has been the establishment of production of .22 rimfire match ammunition for sale throughout Asia and the Pacific rim.

DEDICATION

To the host of friends in the ammunition business who in one way or another helped in my education.

BOOK SERVICE

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INTRODUCTION

The groundwork for this book started over half a century ago, when I joined the Western Cartridge Company as a chemical engineer fresh out of college, with one unique qualification – I was an expert in grinding chicken feathers.

Since that time I have been intimately involved in all phases of ammunition manufacture as well as in engineering, development, sales and service, with some powder making experience as well. My work has been in three companies and five plants, in Illinois, Connecticut, Idaho, Mexico and the Philippines. None of the five has been much like any of the others, except for the basics.

It's been a busy 55 years, but I've still had time for maybe more than my share of shooting competition and hunting, with a good bit of travel thrown in. There have usually been adequate quantities of ammunition to shoot – call it "testing," – as one of the perks of the job.

So I guess, all in all, and particularly if one has an interest in guns and ammunition, which so many do, it's been the sort of job gun and ammunition nuts dream about.

Not that there haven't been occasional harsh moments, some troubled times, five years of war, the wrenches of pulling up stakes, saying goodbye to friends and familiar haunts; and trying periods of settling down in a new community. It has been easier for me than for the family, as I had a continuity of interest in my work.

The changes in location have been broadening, even within the United States. No matter how you slice it, industrial Illinois isn't quite the same as resort and farming Iowa, where I grew up. Connecticut surely isn't much like the Midwest. Idaho is mountains, lakes, forests, and streams, with potatoes and wheat, all Western style. Mexico was a whole new ball game with a second language thrown in. The Philippines, where I now am, is worlds, or more properly an ocean, apart from the U.S. and Mexico, with a daily dose of three languages and a vastly different set of mores and customs to deal with. The variety has always made the job more interesting and more than a little challenging.

Somehow this business has seemed to bring a great many attractive, interesting people together from both sides of the fence – both makers and users. Today's large corporations frown on the non-conformist, but in smaller companies, which Western Cartridge once was, the key people who got things done, who sold the product, and kept it sold, were strong colorful personalities. In the small companies where I've worked, there was a company personality, a warmth of fellowship, pride in product, and a pervading democracy that made working and social life a pleasure. Foremen, executives, and workmen all shot the product they made, and knew firsthand how it should be. Some of these people are named, in the pages to follow, as a small tribute to their help and knowledge.

Over the many years that I went to the Grand American Trap Shoot and to Camp Perry (National Rifle Matches) I shot at a great many matches, brought the word to jobbers' sales meetings, sat in hunting camps, dropped into sporting goods stores, and otherwise met with hunters and shooters. I met a great many grand people and only a very, very few whom I didn't care to know. Our commonality of interest made conversations easy and I learned a lot by listening.

Most shooters have an intense urge to pass on their experience to others. The man from the factory is apt to be somewhat of a social lion if he's a good listener. At the same time, his pronouncements are usually accepted as being fairly close to the ultimate truth. Partially this is true because he's away from home and, therefore, something of a prophet. More important is the fact that he's been closer to where it's happening, in the factory.

The question was asked me many times, and I'm sure it has been asked of most all ammunition "factory men," "Where do I go to learn how to make ammunition?". Young, excited engineers want to get into the business, but would like to approach one of the ammunition companies with more basic knowledge of the subject than can be gotten from the reloading manuals and magazine articles.

The answer isn't, "Go read a book," because there aren't any complete works on the subject, at least none recently. It's not that ammunition makers aren't literate – there are many who can read and write – but commercial ammunition making

has been a small field with only a few companies in operation at any one time. These companies don't favor giving out information they got the hard way to potential competitors.

The bigger makers haven't encouraged competition. In fact, in the past, some smaller makers showing potential have been bought out in order to keep the field small. Other means have been taken to discourage competition, but they haven't always been successful.

Franklin Olin, a good many years ago, needed a bigger market for his blackpowder business, and started loading shotshells, using components made by other companies already in the business. When his business started to grow, his sources of components cut him off. Being an engineer of more than passing ability, in 1898 he quietly began to make his own shells. His shot tower, built in 1903, looked like any one of hundreds of grain elevators dotting the Midwest. He needed brass and began making his own. World War I expanded his activities, and Western Cartridge Company became a full blown competitor, with innovations in cartridges and shells that shook up the business.

In 1931, Western Cartridge bought out the then bankrupt Winchester Repeating Arms Company, one of those who earlier had stopped selling components to Olin. When some of Olin's early engineers quit and set up their own small company in the Alton area, they were immediately bought out. The know-how was kept in the company.

Such things as know-how cannot be kept a secret forever, particularly if there is a market to gain and a dollar to be made. Diligence and a knowledge of the basics can make up for what one can't find in a book. So it has been with ammunition making.

Reloading has been with us since the very first centerfire cartridges and shotshells were made, but today's growth really started after WWII. There was an immediate shortage of components. The ammunition makers, according to their answering letters and published statements at the time, were diverting all their production to filling the war-depleated pipelines with loaded ammunition, so that the hunter could get back in the field. This shortage went on somewhat longer than was necessary, mostly because the major producers feared that reloading was going to cost them some loaded ammunition business. It was 1900, repeating itself.

Not many hardware stores wanted to sell components anyhow. Orders were small, the shipping departments preferred to work on carload orders instead of small packages of components. The paperwork was the same either way. The hardware wholesaler, who was the principal distributor of ammunition in those days, had no interest in warehousing a small volume item. Nor, did his salesman, with 20,000 other items in his catalogue, want to push components to a reluctant retailer.

Still, there was a loud insistent demand for reloading supplies, another manifestation of the national do-it-yourself craze. Again, there was a chance for a small company to jump in and grab the crumbs the big ones disdained.

The first to get in were the bullet makers, R. B. Sisk of Iowa Park, Texas, Speer in Lewiston, Idaho, Hornady in Nebraska, and Sierra in California, among others. Unknown to Western's Ammunition Sales, Sisk was actually buying his jackets by the millions from Western's Brass Mill. Homer Clark started ALCAN to make and sell shotshell wads, and primers and powder imported from Italy.

The powder companies, Hercules and Du Pont, continued to encourage reloading, making cannister powder available, but primers were scarce and most were imported. Which left an opening for another business.

Helped by a refugee named Victor Jaisitis – a Lithuanian with a Ph.D. in Chemistry, and graduate experience in both German and Russian prison camps – Dick Speer set up Cascade Cartridge Inc. to make primers. The business actually started in an abandoned chicken coop (cleaned out first), but grew rapidly. Expansion into the loaded ammunition business was a natural. With the primer know-how in hand and, having grown considerably, the company set up a rimfire ammunition plant in Mexico, in successful competition with Remington's plant there.

By 1962, CCI was producing several hundred million pistol, rifle and shotshell primers a year. Soon after entering the .22 rimfire ammunition market, production grew to several hundred million rounds a year. Omark, who was competing with Olin's Ramset operation in the powder actuated tool business, soon saw the potential in having its own source of power tool loads and purchased the CCI in 1964. CCI had been making Omark's .22 caliber loads.

Helping the several small companies' ammunition business grow was the rise of the sporting goods wholesaler and retailer, taking over from the hardware store.

It would seem that by again trying to discourage reloading, the major companies ended up by creating substantial competition. History forgotten, the early 1900's were revisited as when the American Ammunition Association shut off Peters and Western Cartridge, forcing them into making their own components.

By the time the established makers recognized that reloading was a profitable business and here to stay, and had quit fighting it, several small companies, flexible, fast on their feet, and in close harmony with their customers, ran away with a large share of the component market.

So, it is possible to get into the ammunition

business, even though there isn't any great amount of specific literature on the subject or any place to study it.

It is not the purpose of this book to establish ammunition making as an easy home project or even a cottage type industry. It is simply that there seems to be a deep and continuing interest in all facets of the shooting sports, and it is hoped that this book will contribute to the general knowledge.

But to get back to the chicken feathers.

Some of us have vivid memories, from the 1930s, of a run-down, out-at-the-seat-of-the-pants situation called "The Great Depression." Jobs were as scarce as virgins in a whorehouse. Long lines formed to follow even the wildest rumors of work to be had. We still had a work ethic, then, and didn't like to be unemployed. Getting paid for not working didn't seem quite the thing to do.

Into this situation, I burst forth upon the labor market, slide rule and diploma in hand, with a small, dull thud. With thousands of others, I'd spent the months since my graduation in 1934 writing letters of application, making calls, filling out forms, and getting the normal, "We'll call if we need you" treatment. A three-day bus ride to Old Hickory, Tennessee didn't produce, and hiking on to Chicago for a month of tramping the streets and riding the El was wearing on both soul and soles.

Along came a rumor that a company called Western Cartridge in East Alton, Illinois was hiring engineers. Having been a believer in Peters Ammunition since the age of 14 it seemed a little traitorous, changing brands, but I took the bus, that broke down twice on the way, and landed in Alton on a Friday with the sum total of $1.20 in my pocket and nothing I could hock. The receptionist said it was too late and to come back Saturday to see Dr. Fred Olsen. The dollar went for a sandwich and a night at the YMCA.

Saturday, forms filled out, I was ushered into the "Presence." After the usual "sorry," and on my way out, he said, "Maybe you might have an idea about this problem," and proceeded to describe the company's need for a lightweight filler for use in low density dynamite.

It so happened that my research and thesis in college had been on the use of keratin, a protein component of chicken feathers, to make plastics, much in the manner of using casein hardened with formaldehyde. From the "light as a feather" simile, it was only a short step to thinking, "Why not for dynamite?". As I had been grinding the bulky feathers to make them more manageable in my experiments, I came up with the suggestion. Sweet music! "How soon can you start?" So I went to work as a feather grinder. Pay, 50 cents per hour, unlimited overtime.

The scale in those days was 50 cents for bachelor's degrees, 55 for master's and a magnificent 60 cents an hour for those with PhD's.

Within a year, I had a raise to 55 cents and a joint patent with my immediate supervisor on a material which was not chicken feathers. They didn't work out. I moved on to smokeless powder engineering and primer explosive chemistry.

The company had a string of what turned out to be very gifted assorted degrees working in research. Their work area was, due to space available, in the powder mill where I worked. Their various activities, which I could look in on daily, sharpened my interest in many things beyond my immediate assignment.

This wasn't intended to be autobiographical, but after the opening line, it wouldn't be fair to quit with one shoe dropped.

After having been exposed to this delightful business for so long, some modest amount of the knowledge, lore, and witchcraft to which I've been exposed has rubbed off on me. Of this business, I don't propose to tell all, because I don't know all, but with my ignorance fairly well organized, this book may shed some interesting, if not useful, light on how things are done in the Bullet Works.

One small note: While the laboratory side of my education dealt with things metric, the engineering side has, until recently, been with the English system, and my mental yardstick seems now to be permanently programmed to deal in inches and pounds. The reader may make his own conversions if he wishes.

CHAPTER I
FIRST IMPRESSIONS

The manufacture of ammunition takes a diversity of skills, as the following pages will show. Metal working operations involve blanking, pressing, deep drawing, lathe operation, metal forming, cold heading, annealing and pickling, extrusion, embossing, piercing, shot making, press assembly of metallic parts, and lesser secondary steps.

There is chemistry involved. Sulfonation, nitration, condensation reactions, precipitation of dangerous lead explosives, preparation and handling of hazardous mixtures, plating, chemical disposal of explosive and acid wastes, and pollution control all enter the production picture.

Metallurgy, as it applies to brass, plays a prominent part in laboratory controls.

Loading is a form of automated packaging. So is the packing of the millions of loaded rounds into boxes, cartons, and cases.

Quality control, well organized, is needed to keep the product safe for the user, good in performance, and low in scrap and production costs.

Testing of pressures, velocities, primer sensitivity, functioning, accuracy, and allied procedures is a specialized art in itself.

Tool making calls for a high order of skill and precision.

Safety is a key word in the industry, calling for special designs and measures to protect the workers.

In the following pages, ammunition is dealt with component by component, and it will be seen how the many skills mentioned above blend into making the finished cartridge.

There are special chapters on ballistics, ammunition malfunctions, quality control, and fires and explosions. The subject of accuracy is taken up in one chapter. There is a chapter on .22 rimfire match ammunition, as an extension of the process of ordinary ammunition production. Of interest to some may be the notes on starting up a new operation in a foreign country.

The chapter on ammunition troubles and malfunctions is for Tuesday's reading, to help analyze what went wrong on Monday after a long weekend.

Powders are covered in a general sense, to help show what the manufacturer does to pick a powder for a given load.

Lest the text become too dry, it has been laced with a few personal reminiscences and episodes from my years in the business. A few names are sprinkled here and there. There could be many more who helped make some sort of ammunition history, but most would not ring a bell with the reader.

Tooling detail is included to illustrate a point on principle. The interested reader is left to work out his own particular designs. Elaborate tables of tool dimensions and accompanying drawings are not of enough general value to be included.

There are more paths from raw material to finished product than are discussed here. Some may be better, some may be not as good, as might be expected, when each manufacturer has generally developed his own processes, tools, and some, if not all, the machinery needed.

The reader may note the absence of a bibliography. As mentioned in the foreword, not much that is specific has been written. Most of the material herein is from my own notes and memory. The basic knowledge of the various metal working skills can be found in standard texts on mechanical engineering. Chemistry is straight-forward and can be dug out of high school and college texts. The exact processes, quality controls, and safety precautions are covered herein as practiced at plants in which I've had experience.

It is possible today to approach several European makers of ammunition equipment, each of whom is prepared to deliver a complete line of machinery, tooled for a given caliber. Most of these machines, by changing tooling and adjusting feeders, may be converted to other calibers. Production rates on the machines offered are all nearly the same. One complete line of machines, balanced for production, can produce 40,000 cartridges per shift, about 10 million per year. The European makers follow generally traditional processes. Each step calls for a specific machine.

In the U.S., several companies made ammunition loading machinery during war emergencies. Today, two American companies offer highly complex, integrated machines capable of producing finished cases from cups, as well as bullets from cups, and loading machines of considerable sophistication. These lines can produce up to 1200 loaded cartridges a minute. Such lines are not for the small producer. The lines were generally designed with arsenal operation or very large ammunition producers in mind.

The Lake City Army Ammunition Plant has such a line, part of the Small Caliber Ammunition Modernization Program (SCAMP), in operation.

CHAPTER II
THE CARTRIDGE CASE

Why Brass?

As most everyone knows, brass is the usual material of choice for cartridge cases. However, World War II saw the U.S. making steel-cased, .45 cal. pistol ammunition. Most of the 8mm German ammunition one saw in Europe at that time was steel. Russia currently makes .22 rimfire cases of steel. Aluminum, zinc, copper, and even some types of plastic have been variously tried or used to some extent.

Cartridge brass still remains the best of the various materials. The following pages will give some explanation as to why.

For comparative purposes, the salient physical characteristics of the various possible case materials are shown in Table 1:

Table 1
Physical Characteristics of Potential Cartridge Case Alloys

Alloy	State	Tensile Strength lbs/sq. in. × 1000	Rockwell Hardness R B	Modulus of Elasticity PSI × 10	Elongation % in 2"	Density lbs./cu. in.
Copper	**Annealed**	33	—	—	45	.323
	Hard	50	50	17.0	6	—
95/5 Gilding	**Annealed**	35	—	—	45	.320
	Hard	56	64	17.0	5	—
90/10 Commercial Bronze	**Annealed**	38	—	—	45	.318
	Hard	61	70	17.0	5	—
70/30 Cartridge Brass	**Annealed**	46	—	—	65	.308
	Hard	76	82	16	8	—
Zinc	**Hot rolled**	23–29	—	—	32	.258
	Cold rolled	25–31	50	15	28	—
S2S Aluminum	**Annealed**	27	—	—	25	.097
	Hard	41	52	10.2	7	—
SA 1010 Steel	**Hot rolled**	51	—	—	38	.283
	Cold rolled	56	72	29	35	—

All hardness readings have been converted to equivalent Rockwell B.

The Modulus of Elasticity is a measure of the stiffness of the metal; the higher the figure, the stiffer the metal.

Elongation is a measure of ductility. The figures shown are the % increases in length a 2" gauge-length undergoes under tensile stress before breaking. It will be noted that the more the metals above are worked, the less ductile they become.

With materials other than brass, the necessary compromise between performance, cost of material, and ease of manufacture are seldom favorable for making cartridge cases.

Take steel for instance. The cost per pound is less than ¼th that of brass – a worthwhile saving – but the disadvantages usually outweigh material cost. Steel rusts, and rust is harder than steel. On a steel cartridge case, rust will scratch the chamber, cause difficulty in feeding and, likely, hard extraction. Some surface treatment is necessary.

Steel is stiffer than brass and harder to work, requiring special lubrication in process. Tools wear out faster and break more often. Heavier machines are needed. The resulting case is stiffer than a brass case. In the rimfire case, sensitivity is reduced significantly so that a harder firing pin blow is required.

Performance in the gun is something else. Lacking the springyness of a brass case, the steel case, after expanding in the chamber during firing, doesn't contract as much when the pressure goes down. Further, the coefficient of friction of steel against steel is more than 60% higher than brass against steel. The case is more prone to stick in the chamber. So much more so, that the French, upon introducing a steel-cased version of the 7.62 mm NATO cartridge found it necessary to flute the chambers of their military rifles to facilitate extraction; particularly in full automatic fire.

My own experience, with steel .45 cal. pistol cartridges in Europe during WWII, wasn't good. After being in the magazine for a while, and exposed to frequent spates of excessive dampness, the cartridges generally showed varying degrees of reluctance to feed without jamming. One did a good deal of dry functioning of cartridges through the gun to make sure what one had on hand for social emergencies was going to stand up and be counted, if and when a showdown came.

Brass-cased .45's, therefore, when they could be found, were a premium commodity. On one occasion, I ran into a friendly, souvenir hungry Master Sergeant at an ammunition depot who admitted to having a small cache under his wing. He was persuaded to part with it for the exchange of one of the then fancy new little individual gas stoves just being issued. The stove I had just gotten from a Quartermaster Sergeant, who wanted a newly liberated P38 pistol in exchange. The brass case was a great favorite among our pistol bearers, who no longer had to go through the frequent ritual of shucking steel-case rounds through their pistols. So, except in wartime when copper and zinc are needed for more critical applications, steel for cartridge cases is second choice.

Zinc and copper have been used for cartridge cases. Both metals work easily, are likewise easy on tools and machines. Neither makes an ideal case. Zinc doesn't rust, but is too soft, work hardens very little under processing, and isn't strong enough except for very low pressures. Copper is better, and in fact was used for many of the early black powder cases. It does work harden in drawing and forming, increasing its tensile strength from as low as 32,000 psi to as much as 50,000. It draws and forms well, but doesn't machine well when it comes to cutting cannelures and trimming. Essentially, copper lacks strength enough to stand the high pressure of smokeless powder loadings.

Intermediate between copper and brass are two popular copper-zinc alloys, which have had, and still have, wide use in making ammunition. A mixture of 95% copper, 5% zinc, commonly known as "gilding metal," used to be the one used in such famous old .22 cal. match cartridges such as Remington's Palma Match, Winchester's Precision 200 and Lesmok EZX and others. With the passing of Lesmok powder from the scene, as the switch was made to smokeless in rimfire match ammunition, the use of standard 70/30 cartridge brass became necessary. Lesmok pressures were quite low, down in the 15,000 psi range, while smokeless powder .22 match rounds may run a good 5000 to 8000 psi higher.

In early SuperMatch .22 ammunition, as well as in many other cartridges where some additional case strength was desired, an added 5% of zinc was used, making a 90/10 mixture of copper and zinc. This is still used for bullet jackets.

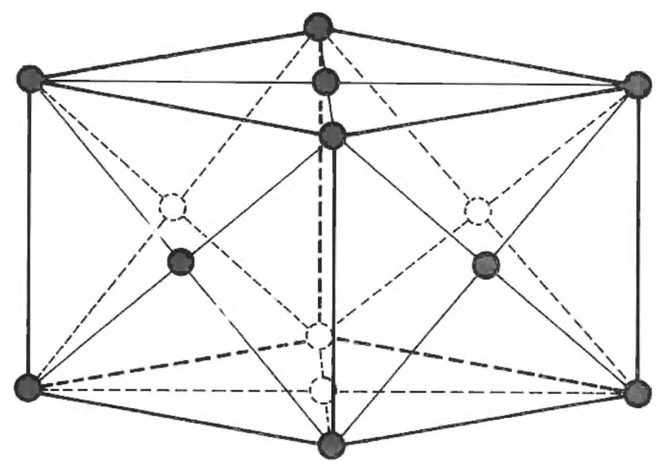
This 90/10 alloy, known in the trade as "commercial bronze," has a tensile strength ranging from 38,000 psi in the soft annealed state to as much as 61,000 psi when fully hard from cold work. It machines better than copper, draws well, but still falls behind cartridge brass when it comes to the task of withstanding the 50,000 to 60,000 psi pressures of modern high intensity loads.

So it can be seen that, as the proportion of zinc in the alloy increases, the utility of the alloy for cartridge case making gets better. But, as noted earlier, pure zinc is of very limited value. Obviously, then, there must be a limit as to the amount of zinc in the alloy.

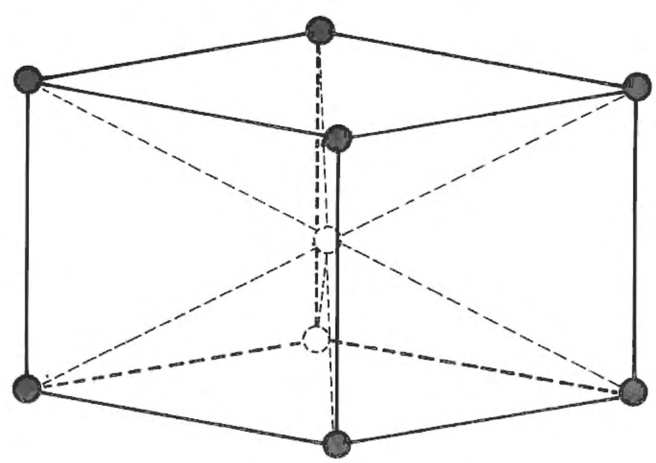
Which brings us to the 70% copper, 30% zinc mix known commercially as "cartridge brass." Here we might dip into metallurgy briefly (about as deeply as testing the water temperature with one toe) to see why this particular alloy gets its name.

To begin with, it must be remembered that an alloy is a metal – or metals – dissolved in another metal. In this case, we're talking about zinc being dissolved in copper – a very simple alloy of only two metals.

Metals, in their solid state, are crystalline substances. Copper crystals have an uncomplimented common shape, a cube (See Fig. 1). The smallest unit in this cube has an atomic arrangement like dice with fives on all six sides, except that the spots at each corner are common to the three faces



FACE CENTERED CUBE



BODY CENTERED CUBE

Figure 1: Copper Crystalline Structures

meeting at that corner. In the middle of each face of the cube is a single copper atom. This crystal unit is known as a "face-centered" cube.

Most of the soft metals, including copper, are similar in crystal structure, and it is this simple cubic structure which accounts for the malleability of these soft metals. Metallic grains of pure metals and certain alloys of these metals built up from these face-centered crystal units are called "Alpha" grains.

When zinc is dissolved in copper, forming the series of alloys known generally as brass, the zinc atoms in part displace or substitute for copper atoms in the cubic lattice.

As zinc is added, up to about 37%, the crystal system remains face-centered, but beyond 37% the grain becomes saturated with zinc, and must change its structure in order to take up any more zinc. The crystal units then begin to change to a different cubic form. Instead of an atom in the center of each face, there is one atom in the center of the cube. This new form is known as "body-centered" cube, and is characteristic of a new form of grain known as a "Beta" grain. The copper atoms at the corner of the cube remain.

When it comes to making things out of brass, the presence of Beta grains introduces a whole new ball game. Alpha brass in the range up to 30% zinc is very workable either cold or hot, but from there on up to the 37% range doesn't work well when hot. Beta grains begin to show up when the zinc content gets beyond 37%, and the alloy works much better hot than cold.

Going from pure copper up to 30% zinc, strength and ductility, as well as hardness, go pretty much hand in hand, increasing as zinc content increases. Beyond 30% zinc, ductility takes a beating. Hot rolling becomes impossible until an increased percentage of zinc brings the Beta grain in.

All this business about the Beta grain may be interesting, but it is not germaine. The Beta brasses aren't ductile enough to make ammunition.

So, to sum it up, at a 70% to 30% ratio, the strength, ductility, and hardness of a copper/zinc alloy all reach a joint maximum, and all three of these attributes enter into making the best and strongest cartridge cases. Hence, 70/30 has become so universally used that it carries the commercial designation of "cartridge brass."

After doing a fair amount of time in the factory, I was moved from the engineering side of the business to the Sales Department, and handed a bundle of duties loosely lumped under the title "Technical Advisor to the Sales Department." One of my frequent odd jobs was that of escorting visitors, distinguished and otherwise, through the plant, with appropriate patter.

One of the plant areas covered was the huge brass mill, and the tour included a pause at the break-down roll. Here freshly cast slabs of brass were run through a non-reversing roll, carried back to the starting side, and rolled again. This went on until the cold-work attendant to the reduction in thickness made further rolling difficult. The elongated strip then went to the annealing furnace and then back to the roll until the slab had been worked down from its original 2" thick mass to about a fourth of that. The break-down process on one billet took the better part of two days elapsed time.

It was a pleasure, later, when hot rolling, with reversible rollers like those in a steel mill, was instituted, to make a two-minute stop. The red hot brass zipped back and fourth through the rolls, getting thinner and longer each trip. In less than two minutes, the earlier day's break-down work was done. It was impressive to both visitor and guide.

During World War II, that same brass mill, without much increase in building size, put out as much finished strip brass per week as it had made per year in the days of the old break-down roll.

In the realm of packaging, today's cartridge is a unique blend of utility and simplicity. In a highly functional unit, a package of energy is ready to be delivered instantly and reasonably efficiently when properly called upon, i.e. you do need a gun to shoot it in.

It isn't the purpose of this book to dwell on the history of the cartridge. Far better writers have already covered the subject thoroughly.

Evolution of the cartridge case came rapidly after the inventions of D. B. Wesson and B. Tyler Henry showed the way, and repeating rifles and revolvers came into use.

However, other than for producing a variety of shapes and a myriad of calibers, little has been done in the past century to change or modify the basic cartridge system. The cartridge case today is still basically the same time-tested means of containing powder, primer, and bullet in one neat package.

The case itself hasn't changed much, except in changes in construction to match increasing pres-

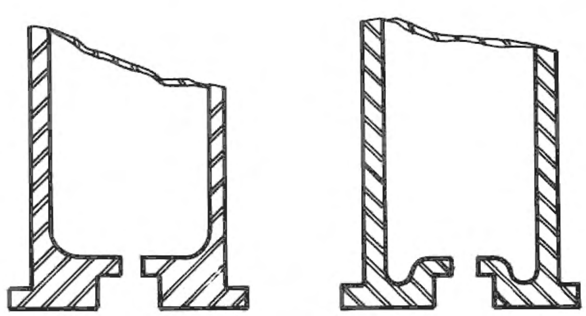


Figure 2: Typical Case Head Construction

sures. Head strength has been increased by going from the early material-saving "balloon" type head to the solid type (See Fig. 2). The balloon type was okay for low-pressure blackpowder loads. Methods of manufacture have undergone considerable change, much of it in the interest of higher production rates utilizing less labor.

The basic process of blanking a disc from strip, forming a cup, drawing the cup, trimming it, and finally, heading it, ready for spinning in the priming, is still the way by which a rimfire case is made. Modern presses with special, quite-sophisticated progressive dies, take the strip and progressively punch out a drawn case all trimmed and ready for heading, at rates up to 1,000 cases a minute. A small producer of ammunition may have a problem in justifying such a machine, unless he has a market to fit or unless he uses the press for other things as well.

To get back to fundamentals, a good machinist can make simple tooling, and, using hand toggle presses and a small lathe, can produce a very satisfactory rimfire case. A drill press can take the place of the production primer spinner. The catch comes in how to prime the case – to be discussed in a later chapter.

A centerfire case, on the other hand, isn't quite so easily produced in the home workshop. Much higher tonnages are needed to blank, cup, and draw the case, but it can be done with truck-sized hydraulic jacks for presses. Heading, where the primer pocket is very critical, becomes quite difficult, in fact nearly impossible, without a large heavy crank press.

A few cartridge cases, made by people needing an odd caliber no longer offered, are turned on a lathe from solid stock. It is not a very cost effective method.

One modern method of producing a centerfire case starts with brass rod or wire in coils. A machine, similar to the one used to make common nails, called a cold header, feeds in the rod, cuts off a piece large enough to make one case, and transfers it to a cavity in the machine, where it is struck by a punch. This forms the irregularly shaped cylindical piece into a precise sort of button shape.

The button is annealed, then fed into a two-stage transfer press which transforms it into a low, fat cup. The half-formed cup is transferred to the second step, where it is pushed through a die that draws it to its final dimensions (See Fig. 3).

The cup, after a second anneal, then goes through further draws in separate machines to become the finished cartridge case.

Two U.S. companies and at least one European company offer composite machines, which will take a standard cup, draw it, trim it, head it, anneal the body, neck it, trim the head, anneal the mouth, and finally trim to length, and deliver it at the end as a finished case, at rates up to 600 per minute.

Such machines are fine for larger scale production of military cartridges of a single caliber, but don't fit too well in making commercial cases. Sale volume for any one commercial caliber is usually not large enough to warrant the cost of the extra tooling. The expense of frequent changeover, plus the cost of amortizing a multimillion dollar machine in a reasonable length of time, prices these machines out of the commercial market.

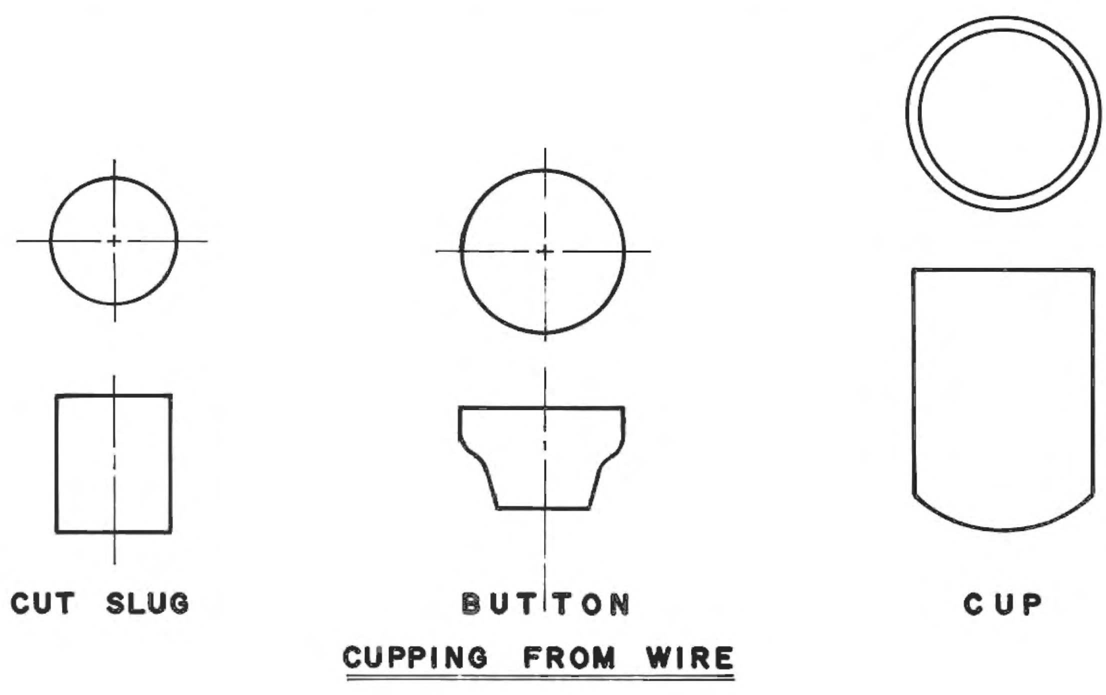


Figure 3

The cartridge case is called on to do a variety of jobs. It must contain the powder charge and primer. It must seal off the rear of the chamber when fired and contain the immense pressure inside, yet permit the case to be removed with ease after firing. It must hold the bullet in place when carried in carton, magazine, or pocket, tightly enough to keep atmospheric dampness out, yet release the bullet to travel down the bore under pressure from the powder. It must hold the primer tightly in place during firing, so that it doesn't fall out to jam the firing mechanism.

With all these requirements, the case must vary in hardness – from very hard for maximum strength in the head area, medium hard with good elasticity in the body area, and soft at the neck or mouth end where the bullet is seated.

If the case is too hard at the mouth, it will split eventually under the continued strain of holding the bullet in place. This type of split, called season cracking, may also occur in the head or body, if the material has been excessively cold worked.

Back in my high school days, we had a rifle club in town which had a 200-yd. outdoor range, where, through the courtesy of the Director of Civilian Marksmanship and the NRA, we had a goodly quantity of World War I-vintage .30-'06 ammunition to shoot on Sundays.

Much of this WWI ammunition had split necks, and we used it for slowfire, where the cartridge could be loaded carefully in the rifle without displacing the bullet.

Occasionally, too, one of these cases would split near the head on firing, and a spit of gas would come back to sting the face or eye. We more or less accepted the trouble then as being due to "old ammunition" (only ten years).

Years later, when my ammunition making mentor, Victor Crasnoff, a former ammunition inspector for the Czarist Russian Government, and I discussed this problem, he said that it was the Russians who introduced case neck annealing into U.S. practice. The Czarist government had required that Western anneal the necks of cases made for its use in World War I. After the war Western simply adopted the practice, now universal, for all bottleneck cartridges.

Checking the effect of strains in other areas of the case is accelerated by means of the mercury cracking test, which shows potential splits, in minutes, that might otherwise take years to develop. In this test mercurous nitrate is applied to artificially over-stressed areas and splits occur very quickly.

Today's cases, with better means of measuring hardness, better metallurgical controls, and many more years of manufacturing experience behind them, seldom show any tendency to split.

Though brass is the best case material currently available, aluminum has also been used with some success – and is currently being used, as we shall see – for pistol cartridge cases and shotshells.

Recently Cascade Cartridge (CCI) has produced a line of pistol and revolver cartridges having aluminum cases. These are Berdan-primed, and not intended for reloading. Doubtless there are some who will try reloading them, just for the challenge. They will not find it particularly rewarding.

From a cost standpoint, aluminum has a tremendous advantage over brass. A pound of brass, punched at 60% efficiency, yields about 50 cups suitable for making .38 Spl cases. A pound of aluminum wire, properly cut and headed can be used to make about 250, .38 Spl case cups. There is virtually no waste. Given the difference in cost between aluminum and brass, and not considering that scrap brass can be reprocessed, the advantage, for cups alone, is about 5 to 1 in favor of aluminum.

Additionally, aluminum can be impact extruded far more easily than can brass. This method, if used, produces a case that is fully formed and needs only trimming to length, head turning, and flash hole piercing for completion. Brass, on the other hand, requires blanking and cupping, annealing, pickling and washing, one or two draws, heading, head turning, trimming, and piercing to complete the case. Labor costs for aluminum cases are only about 50% of those for brass cases.

So why not use aluminum all the way? Because the only real advantage of aluminum is the reduced cost of making the unloaded case, that's why.

For example, even though it work hardens as the case is formed, the tensile strength of aluminum is less than that of copper, its hardness is very low, and the coefficient of friction between aluminum and steel is higher than that of brass against steel. An aluminum case doesn't have much springback, either, so reliable extraction requires some added treatment of the outer surface of the case. Usually this means anodizing the case and coating it with a wax of some sort. And, that's for pistol ammunition.

With shotshells there is the added matter of a crimp. A star crimp, like that used on .22 rimfire shot cartridges, works, but the metallic shotshell crimp is somewhat prone to splitting at the case mouth. Reloading, then becomes unsatisfactory.

One alternative is to use a top wad held in place with a light rolled crimp. This type of crimp will permit some reloading. Unless a frangible type of top wad is used, one gets back to the old days when "blown" patterns were a common excuse for missing a shot. "Blown" refers to a hole in the pattern caused when the top wad got in the way of the shot column – which it really did sometimes though not as often as it was used as an excuse. Older shooters will hark back to the early days of

the ballyhoo on the introduction of the present folded crimp. Elimination of blown patterns was featured in many an ad.

Aluminum shotshell cases are fairly easily formed by impact extrusion from a round blank. Any one of several alloys can be used, starting with the softest, 2S (now called 1100), and going on through progressively harder, tougher 3S, 4S and 5S (3003, 3004 & 5052) types, for example. These alloys are non-heat treatable, and depend on cold work for hardening.

Aluminum shotshells are easily dented. They are certainly water-proof, if the crimp is properly sealed. The shells can be dyed almost any color after anodizing.

Being thinner walled than paper or plastic shells, the volume inside the shell is greater for a given length. The contents of a standard 12 ga. $3\frac{3}{4}$-$1\frac{1}{4}$ oz. loading, normally using a $2\frac{3}{4}''$ plastic shell can be stuffed into an aluminum shell less than $2\frac{1}{2}''$ long, and even magnum loadings could be put in a $2\frac{3}{4}''$ rather than a 3″ shell.

Still, the fact remains that aluminum does not make a good shotshell. Paper or plastic are the materials of choice for the tube; brass plated steel, or brass are best for the head. Brass will remain the primary material for quality, reloadable, metallic cartridge cases, too.

The pages to follow in this chapter discuss briefly the various steps in rimfire and centerfire case manufacture.

Rimfire Cases

By far the largest production of ammunition is in rimfire. U.S. production amounts to between 3 and 4 billion rounds per year, and much is made in Europe and elsewhere around the world, including Mexico, where I once worked, and in the Philippines, where many, many millions of rounds of .22 rimfire ammunition are produced and exported every year. Australia had two ammunition plants, one was Winchester, the other Eley. Eley is now made in Manila. Even New Zealand has a .22 rimfire ammunition and shotshell plant.

A rimfire case is far simpler to make than a centerfire case, but making a good rimfire case is still a painstaking business.

Start with the brass. Not just any brass bought at random from any available source, but highly uniform 70/30 brass with close thickness tolerances, annealed to precise grain size, in coils of a specified size.

Why so fussy about brass?

In all ammunition making, processes are highly repetitive. Machines may run at rates up to 200 or 300 strokes per minute, sometimes 24 hours a day. If the brass varies, the process will vary; scrap increases, tool alterations may be needed, and annealing furnaces must be readjusted. Work in process must be more carefully segregated. Odd sized coils don't fit the feeders. Deliveries suffer. Above all, quality gets spotty. Customers get mad. That's why so fussy!

Thickness of the brass strip used for making .22 rimfire cases varies somewhat with different ammunition manufacturers. Some use strip of .0175″ to .0185″ thickness. Others go a thousandth higher, .0185″-.0195″. Still another buys .0195″-.0205″. All will complain if their brass exceeds tolerances either side. If brass arrives too thin, the drawn shell may end up too short to trim; maybe not every shell, but enough to make too much scrap. Brass that is too thick also creates waste. The shell is longer than necessary, and the extra trim goes in the scrap barrel at a much lower value than it had in strip.

Grain size relates to hardness and drawing ability; the smaller the grain size, the harder the metal. Tools made to work in one grain size range may not work as well in some other range. Too fine a grain might blank and cup satisfactorily, but will need more time or a higher temperature in the annealing furnace. Too-coarse grain brass may not work harden enough in drawing and surface finish may show "orange peeling." Typical hardness for annealed brass of .010 mm grain size is about 88 on the Diamond-point hardness scale, while that of .050 mm grain is 63, a considerable difference.

Grain size is usually read by polishing and etching a piece of strip, then comparing the grain structure at a magnification of 75x with a standard series of pictures of brass polished and etched and magnified to 75x, showing grain sizes as read by the American Society for Testing Materials (ASTM).

Rimfire brass strip seems to be fairly universally specified to a grain size of .030-.050 mm, although .035-.060 and even .060-.090 have been used. A narrow range is probably more important than the exact size.

Some manufacturers make the case with two draws rather than one, with an intervening anneal, pickle and wash. Either the single or two draw method uses a total of three or four dies, stacked, either two and two for the two-draw process, or three or four in one draw. The single draw is less complicated by four operations – one draw, one anneal, one pickle, one washing – and was used in three of the plants I've been in. Two others in which I've worked, and one other I've seen, use the two-draw process.

Advantages of the two-draw process are that it permits slightly closer control of final case hardness and gives less side wall thickness variation.

In a typical rimfire operation the brass would be specified as follows:

70/30 cartridge brass
Thickness .0185″-.0195″
Grain size .040-.060mm

Strip width $5\frac{1}{2}$" (for 9 cup blank and cup)
Coil center hole die 7" (to fit variable coil feeder)
Coil weight 150 lbs. approx. (depends on feeder and handling facilities)

A 150 lb. coil will produce from 61,000 to 65,000 cups, depending on punch spacing. Obviously, if provision is made for handling heavier coils, there will be savings in downtime needed to change coils. One man can handle 150 lbs. without much extra equipment.

The case process is in the following steps:

1. Blank and cup
2. Anneal, pickle and wash
3. Draw
4. Wash and dry
5. Trim to length
6. Head
7. Relief anneal
8. Pickle, bright wash and dry
9. Prime and dry

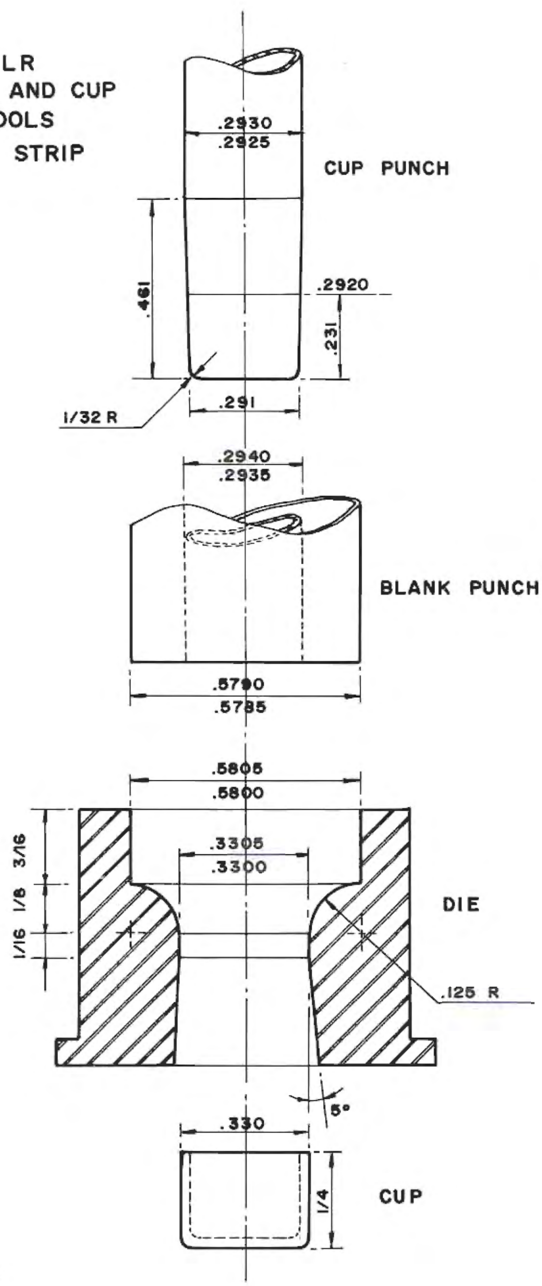


Figure 4

Blank and Cup

Brass on hand, the first operation is to form a cup from the strip. A double-action press is conventionally used. In the press there are two rams, one inside the other, run from a single crankshaft. The cranks operating the rams are timed so that the inner ram lags the outer by about 90°. The outer ram carries the blanking punch. The inner ram carries the cupping punch, which works through the blanking punch.

The blanking punch descends and blanks a disc into the die. The cupping punch follows, centered on the disc, and pushes it on through the die to form a cup and size it (See Fig. 4). Both rams start to rise, the cupping ram still following. As both punches clear the die, the feed mechanism advances the strip for the next row of blanks.

The sketch below (See Fig. 5) shows punch arrangements and spacing.

There is no agreement among manufacturers as to the number of punches used in cupping. The number ranges from as few as 5 to as many as 12. Strip width and coil size and weight are chosen by the user to fit his machine.

The more punches the higher the "strip efficiency," the ratio between usable cups and total strip weight.

Rimfire strip efficiency runs between 65 and 70%.

Work from each punch is kept separate until it has been checked.

The features of the cup requiring control are outside diameter, bottom thickness, wall thickness, sidewall thickness variation, and evenness of cup height.

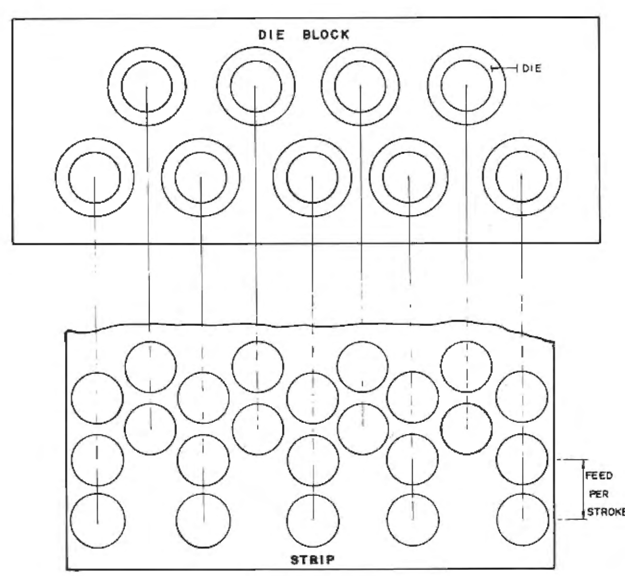


Figure 5

Outside diameter cup tolerance is in the neighborhood of .005". The cup must fit the draw press feed mechanism and center well in the draw die.

Bottom thickness should be kept above .016" to produce a satisfactory drawn shell. Sidewall thickness variation should be kept below .004", preferably below .003". An even-height cup feeds and handles better. A cup of uneven height will generally have excessive wall thickness variation as well.

A typical blank diameter is about .620" for .019"-thick material, producing a final cup, outside diameter of .353" and a bottom thickness of .0185". Cup height will be approximately .250".

To show that there is latitude in cup dimensions (but not much in tolerances), another typical blank, starting with metal thickness of .019", could be only .610"-diameter, producing a cup of .330"-diameter, bottom thickness .018", and would also produce acceptable drawn cases. The difference is in the draw tooling.

Lubricant used in drawing may be a 0.5- to 1% soap solution, or a variety of newer formulations.

The cup next goes to annealing.

Anneal, Pickle and Wash

The cup may be given a rinse to remove the cupping lubricant, and then goes to the annealing furnace. The brass in the sides of the cup has been hardened by the cold working. The bottom of the cup has not been worked to the same degree, and is softer.

Anneal is a matter of time and temperature. It could be for one hour at 1150°F, or for fifteen minutes at 1250°F, depending on the furnace used. A batch furnace would normally be run for the

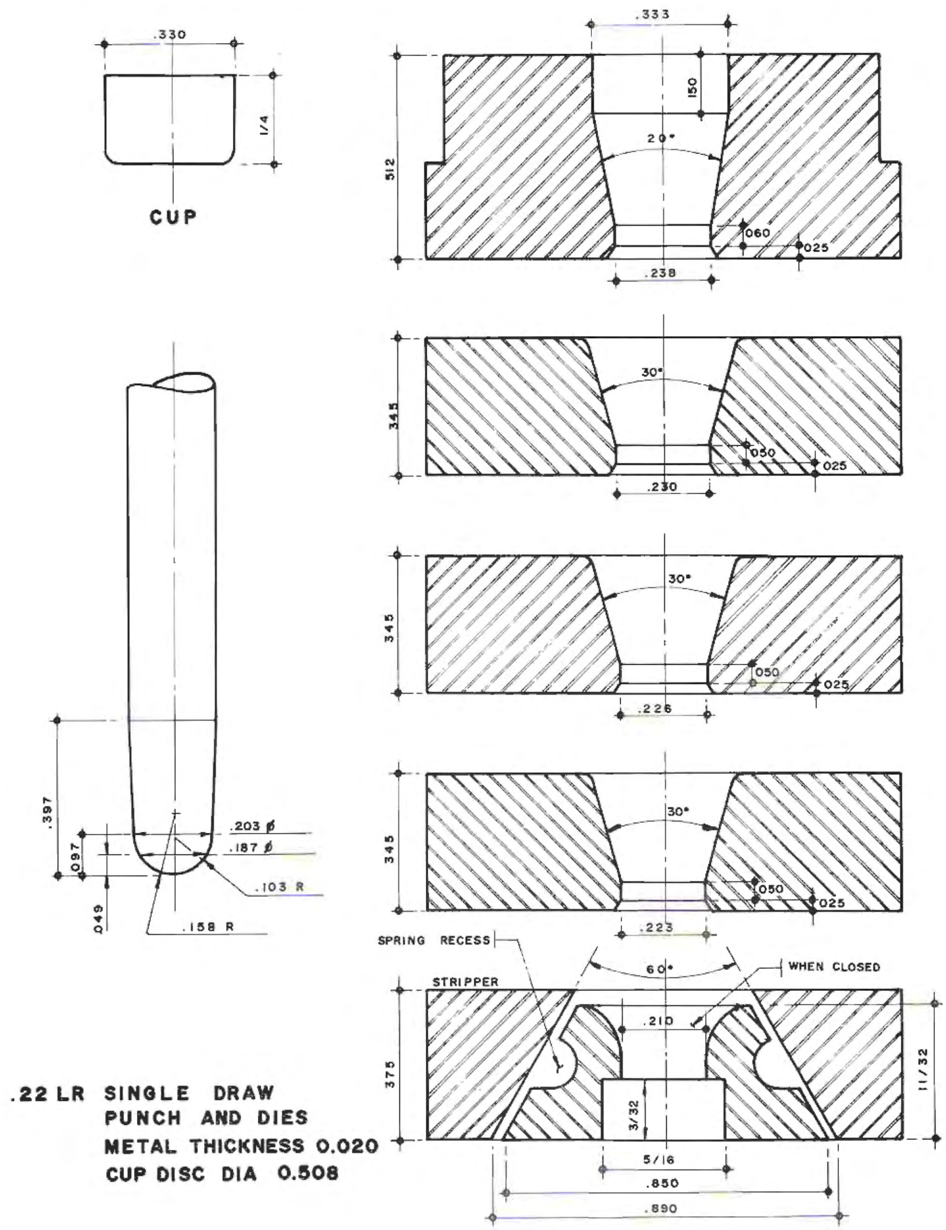


Figure 6

longer time at the lower temperature, so that the heating of the batch would be more uniform.

The shorter time-higher temperature is possible on a belt fed furnace, where the material passes through the furnace in a relatively thin layer on a belt. A continuous rotary furnace would serve the same purpose, as the material would be tumbling over and over to become evenly heated.

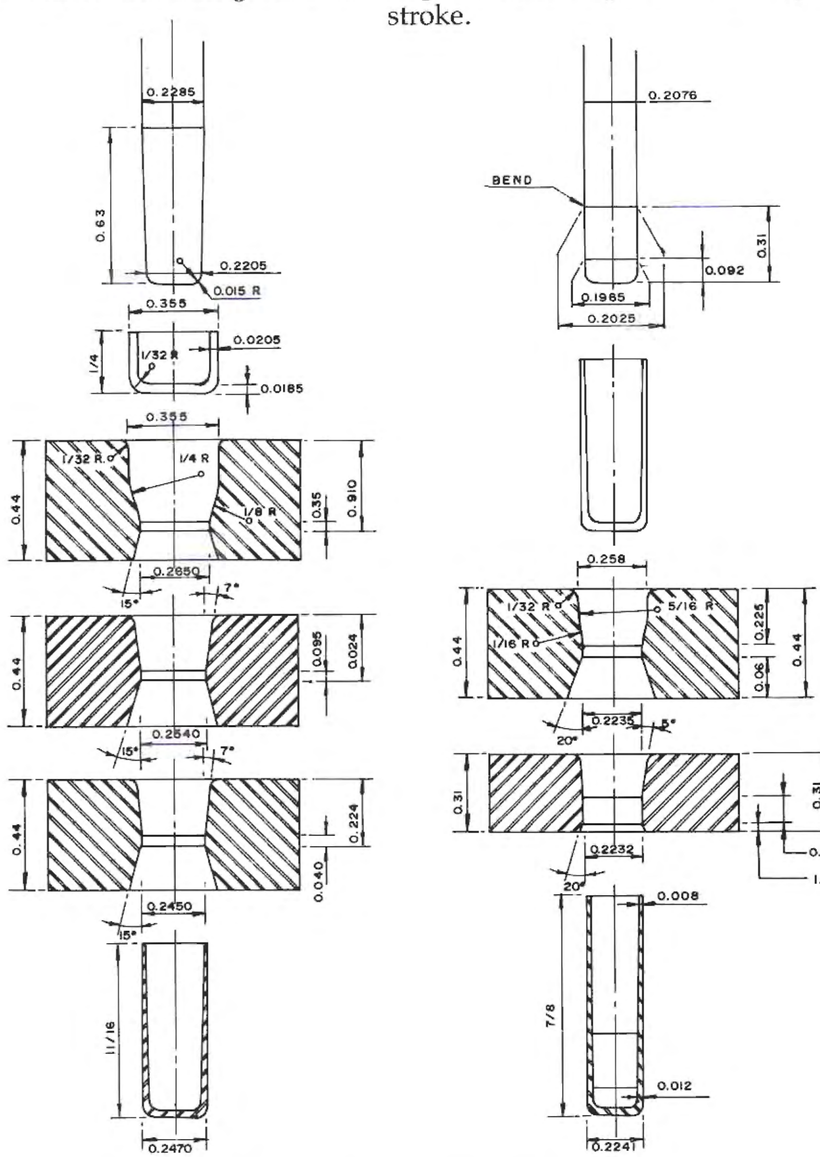
In the annealing process, cups are heated to a temperature higher than that at which grain structure begins to change (the "critical temperature" for the particular alloy) and crystals begin to grow larger. The small, harder crystals in the cold-worked sides of the cups grow quickly; the larger, softer crystals in the unworked bottoms of the cups build more slowly. Typical grain size in the annealed cup would run between .050 mm and .065 mm, starting with .030 mm to .050 mm grain size in the strip.

The annealed cups are dumped into water, or into the wash section, and cooled. Next comes a 4% sulfuric acid pickling treatment, which removes the oxide scale formed during annealing. The pickle and wash are commonly done in a rotating tub. The tumbling cups bump against each other to aid in cleaning off the scale.

After pickling, the acid is rinsed off, and the cups are soaped, then rinsed and dried. A thin soap film may be left on, to help as a lubricant in drawing.

Drawing

Figure 6, shows the punch and die layout for the single draw process. *Figure 7*, shows the same for the two draw process. The stripper in *Figure 6* is a three-piece expandable die which allows the cup to pass, then strips it from the punch on the upstroke.



.22 LR 2 DRAW DIE SEQUENCE
METAL THICKNESS 0.19"
CUP DISC DIA. 0.625"

Figure 7

The draw press may be either vertical or horizontal. One plant in which I worked, used vertical double crank presses, dial fed, each crank powering two punches, producing four drawn cases per stroke. Another plant used a horizontal press with two punches. The choice of press in this regard is one of economics, convenience, and availability. The closer the machines are grouped together, and the more punches per machine, the lower the labor cost. One operator should be able to handle at least eight punches.

Work from each punch must be kept separate until checked.

Punch shape is very important, and must be maintained, so that all punches used are alike, as checked using an optical comparator.

A check of drawn material should be made for uniformity of outside diameter, over-all length, and sidewall thickness.

The drawn case should have a diameter between 0.2240" and 0.2245". Overall length should not be less than 0.875"; sidewall variation should be less than .0015"--.0005" for match.

In the two-draw process, the first draw diameter is that shown in *Figure 7*. Sidewall variation should be less than .003".

Following the first draw, the cup is annealed, pickled, and washed before going to the second draw.

Anneal temperature and time are adjusted to give a grain size of .045 to .065 mm.

The cups then go to the second draw, following the dimensions given for the single draw case (See Fig. 7).

Drawn cups are washed with soap, rinsed and dried. The cups then go to trimming.

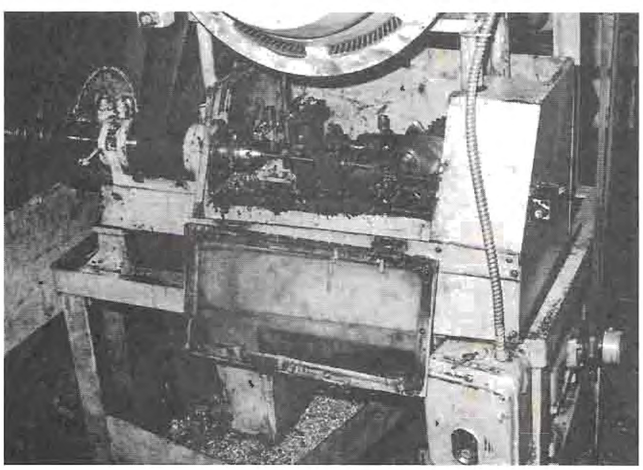


Figure 8: Rimfire Case-Trimming Lathe

Trimming

The trimmer is most frequently of the lathe type (See Fig. 8). The drawn case drops down in line with the rotating collet. A punch pushes the case, head end first, into the collet to the proper depth, a cam operated cutting tool advances and cuts off the open end of the case. The trimmed case is pushed on down the hollow spindle by the next case, and is eventually forced out of the spindle. The trim scrap falls down separately from the cutting knife. The case is now ready for heading.

Length of the trimmed case is dependent on the shape of its closed end. Length is adjusted so that after heading the head is of the proper diameter, and the headed case is of the proper length. Trim length is ideally held to a variation of less than .003".

Control charts are generally kept on trimmed length.

If the case is short and proper headed length is maintained, head diameter will be too small. A too-long case will make a too-large head.

The trimmed cases, still clean and dry, go next to heading.

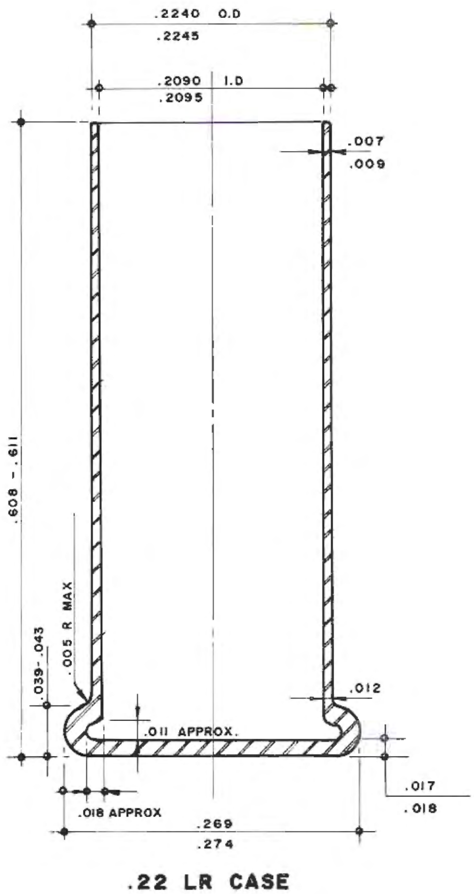
Heading

Heading tools and case dimensions are shown in *Figure 9*. Heading is the most critical operation from the standpoint of control of the several dimensions involved:

Head diameter
Head thickness
Priming cavity size and shape
Head shape under the rim
Overall shell length

On the header, an inside heading punch carries a case, closed end forward, into the heading die. The case, in position, protrudes beyond the face of the die, held by a step on the inner punch. A heading punch, moving against the end of the case, flattens it out, and at the same time, impresses the head stamp.

The header is a specialized piece of equipment, known as a "crank and toggle press" (See Fig. 10). The crank and toggle press has a central die holder with two opposing rams working against it. The inner heading punch has a shoulder against which the mouth of the case rests. This punch passes through the feeder, picking up an unheaded case, which it pushes through the die, so that the head end of the case protrudes on the far side. Timing of the two rams is such that the inner punch and ram dwell at this point. The heading ram, with its punch bearing a reverse of the desired head stamp, then moves forward, marking the end of the case. The head flattens out to final dimension, and the head stamp is embossed in the head. The two punches then recede, leaving the headed case in the die. The next unheaded case, entering the die, forces the headed case out, and it drops into the work basket. Rimfire single case headers work at about 150 cases per minute. Some headers using 3 punch sets form up to 3 heads per revolution.



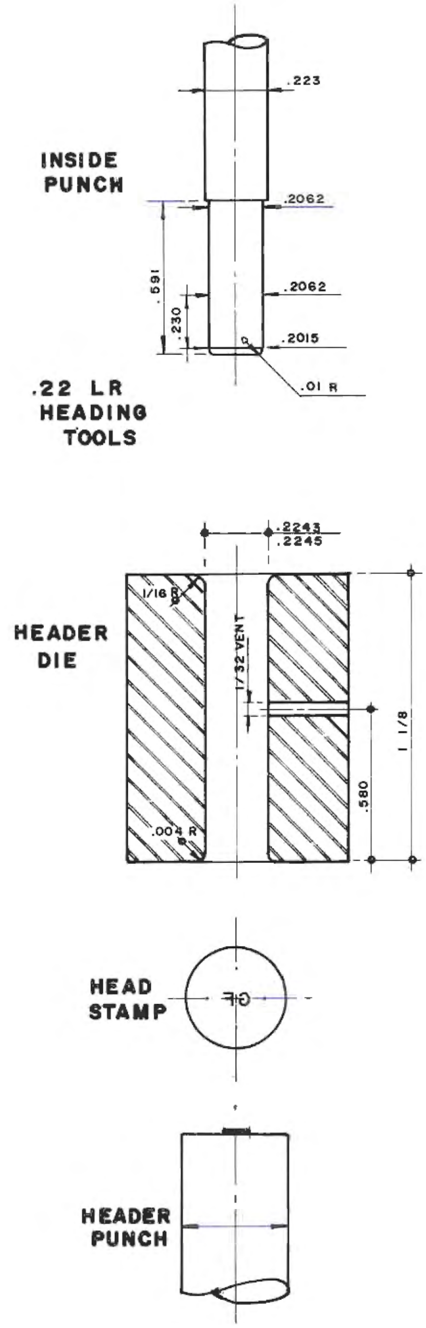


Figure 9: Rimfire Heading and Headstamping Punches and Dies. Head Case Dimensions Shown at Left

It might be noted that the length of the end portion of the inner punch is greater than the final length of the headed case from inside the head to case mouth. This is because there is some slack as well as spring in the ram bearings and toggle. The first motion of the heading punch against the case starts the bend of the brass around the mouth of the die. Following motion pushes the punch back, taking up the slack and providing a firm support for the embossing of the head stamp.

Cases sometimes will show a rippled appearance on the sidewall after heading. This is a result of too much sidewall variation. The thin brass on one side gives under heading pressure, wrinkling in the space between punch and die.

Heading of rimfire can be done on a simple crank press. At Squires Bingham, thousands of .22 WMRF cases were headed on a small $2\frac{1}{2}$ ton crank press, hand fed. Tooling was simple. (See Fig. 11) The inside heading punch in its holder was cammed upward as the holder was drawn back from the press toward the operator. This raised the case so it could be picked off by the operator, who then put a new unheaded case on the punch. The operator then pushed the punch assembly forward under the press ram carrying the outside heading punch. Tripping the press brought the heading punch down to head the case and stamp it.

Adjustment of the easily replaceable inside punch was made by grinding overall length and shoulder

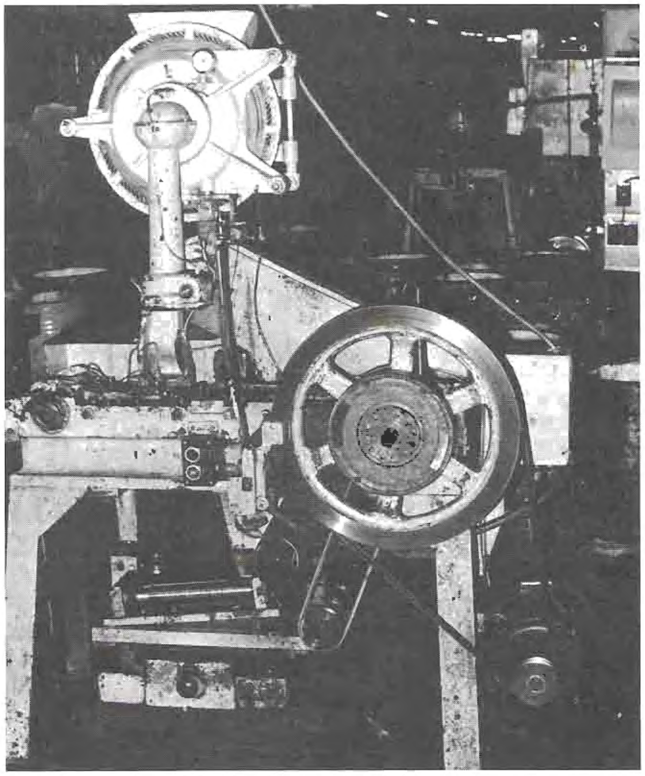


Figure 10: Crank & Toggle Press for Heading Rimfire Cases

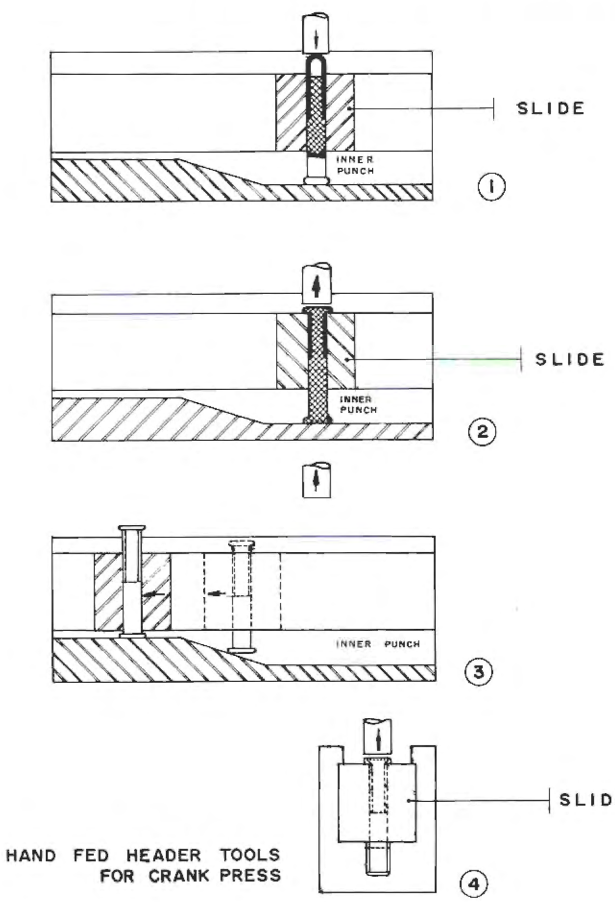


Figure 11: Hand Fed Header Tools for use with Crank Press

length. Adjustment of ram controlled head thickness and diameter.

Following heading comes relief anneal and final pickle and wash.

Relief Anneal

The next step, relief anneal, is necessary to ease the stresses in the head caused by the sharp bending of the metal as the head is formed.

If the stresses are allowed to remain, the case is apt to crack across the rim when fired, or in an extreme condition, may crack spontaneously after storage for a time, even before firing.

Cracks usually form across the rim, rather than around its circumference.

Cases are annealed either in a batch furnace, or on a continuous belt, or in a rotary furnace. Temperature is held below the critical recrystallization temperature of brass, approximately 530°F, to be safe. A temperature up to 575°F could be used if the brass is only exposed briefly. Short of recrystallization, the anneal does not appreciably weaken the brass.

Final Pickle and Wash

Since relief anneal again leaves a dark oxide film on the brass, a final acid pickling, again using dilute sulfuric acid, is necessary. The pickled cases are then very carefully washed, followed by a thorough rinsing, and drying. The cases are then ready for priming.

Centerfire Cases

As with rimfire, most centerfire cases start from brass strip. However, there is a process, mentioned earlier, which started from brass rod. Either way the initial product entering the case process is a cup. From the cup to the finished case, the process is essentially the same. The only variance between strip cup and rod cup is initial cup shape. A somewhat taller cup may be made in the two-stage press from rod. This may make it possible to eliminate one draw stage in the lengthening of the cup to the drawn case.

The usual steps in making a case are:

Blank and Cup from strip or Cold head slug from rod
Anneal Slug
Cup from Slug
Anneal, Pickle & Wash Cup
First Draw
Anneal, Pickle & Wash
Second Draw
Anneal, Pickle & Wash
Third Draw
Anneal, Pickle & Wash
Fourth Draw
Trim
Bunt (optional)
Head

Body Anneal (for bottleneck cases)
Taper and Neck (for bottleneck cases)
Length Trim (may be combined with Head Turn)
Head Turn
Mouth Anneal (for bottleneck cases)
Pierce Flash Hole
Seat Primer
Crimp Primer (for military ammunition only)

The case is then ready for loading as sporting ammunition. Military cartridges are lacquered at mouth and primer before loading. Primer lacquering, frequently used on pistol and revolver cartridges, is a secondary operation at priming.

Some manufacturers also gauge the case before loading. This step is dependent to a degree on the number of defective or out-of-gauge cases the process is making. If the loaded round is also gauged, it may not be economic to gauge twice to eliminate a very few defects before loading. There is latitude in arranging some of the case operations, depending on the case, the manufacturer's choice, and the machines available.

The number of draws from the cup may be two, three, or four. Straight-sided pistol cases may need only two, while a longer rifle case may need four. Cases of .30-'06 length are commonly drawn in four draws.

Intermittent trims may be added after the second and third draws to facilitate feeding at the next operation.

The head may be trimmed immediately after heading, and frequently is with short straight cases. The flange from heading may be left on the head where tapering and necking is to follow. The flanged head provides an easy means of extracting the case from the neck forming dies. Optionally, the case may be pushed out of the die. Pushing has a disadvantage, in that the pusher sometimes dents the inside of the case at the head. This denting may lead to split heads and case bodies because of the stresses created. Particularly, the small .22 cal. cases such as .223 Rem. may have this trouble, as the pusher has to be less than .22" diameter, creating a localized stressed spot in the head. The flash hole may also be closed in. Table 2 shows the typical metal, blank cup and draw dimensions for various cartridges.

In some machines, the head is turned at the same time the case is given its final length trim. Tool adjustment has to be coordinated carefully in this type of machine, to avoid excessive scrap.

Piercing the flash hole is frequently done before tapering and necking, particularly when making smaller-caliber cases. Straight cases are often pierced on the priming machine, so that inadvertently unvented cases are not primed. Piercing is then followed by a probe to verify the presence of the flash hole.

Blank and Cup

The metal for centerfire cases varies in thickness, depending on the amount of metal in the head, as well as the total brass in the case.

A strip as thick as .125" works well for .30 Carbine and .38 Spl. The .223 Rem. case uses .140" metal. The 308 Win. (7.62 mm NATO) is still thicker at .150" to .160", depending on the maker.

As with rimfire cups, a double action press is needed (See Fig. 12). The number of cups per stroke is dependent on press tonnage, as well as considerations of strip efficiency. Strip efficiency is the percent of the total strip that ends up as cup.

Press tonnage to blank the strip can be estimated by the total area of brass sheared per stroke. For example, blanking seven cup blanks of .680"-diam. from a .140"-thick strip would shear a total area of metal of 7 × .680" × 3.14 × .140" or 2.1 sq. in. (See Fig. 13). Since the shear strength of brass is approximately 34,000 lbs. per sq. in., the total press force is about 36 tons. This is with sharp dies and punches. As the tools dull the force required increases. Naturally, the press used will be rated

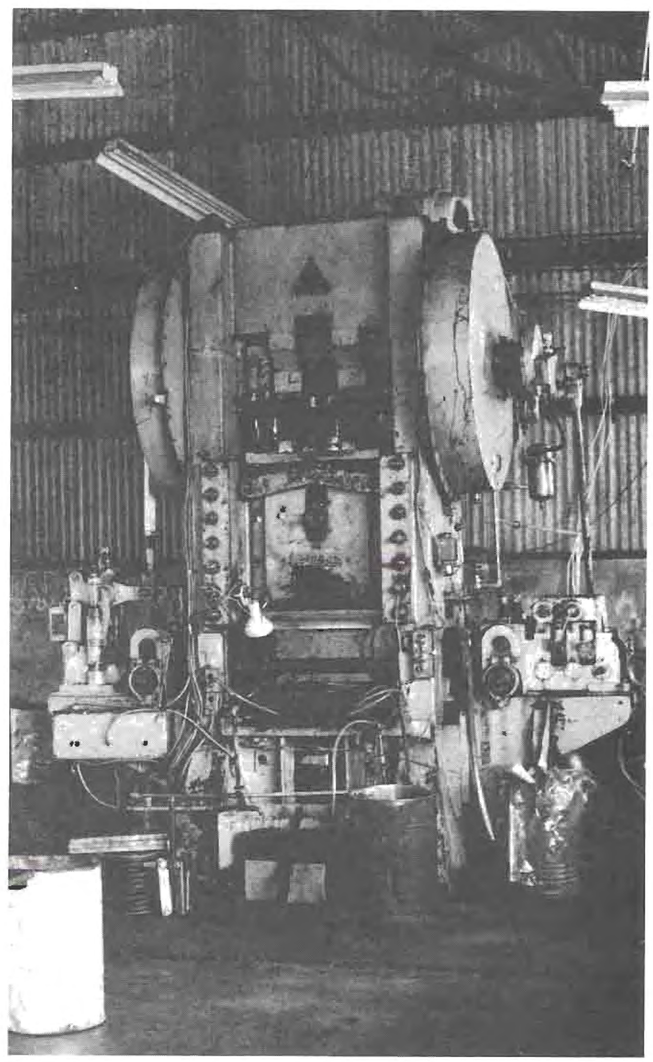


Figure 12: Double Acting Press for Centerfire Cup Production

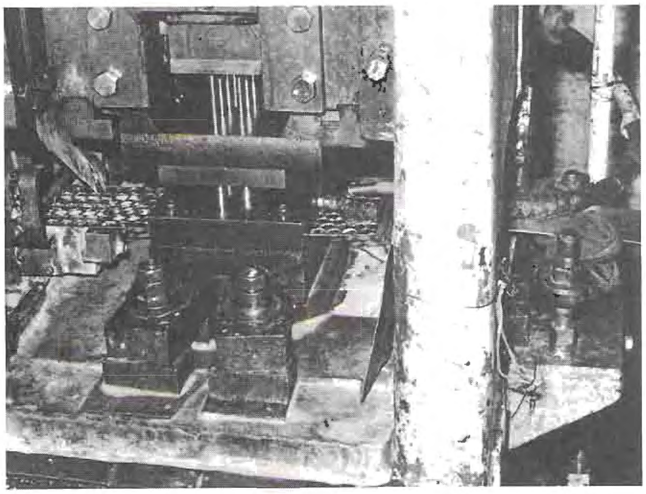


Figure 13: Blanking and Cupping from Strip-Centerfire Cups

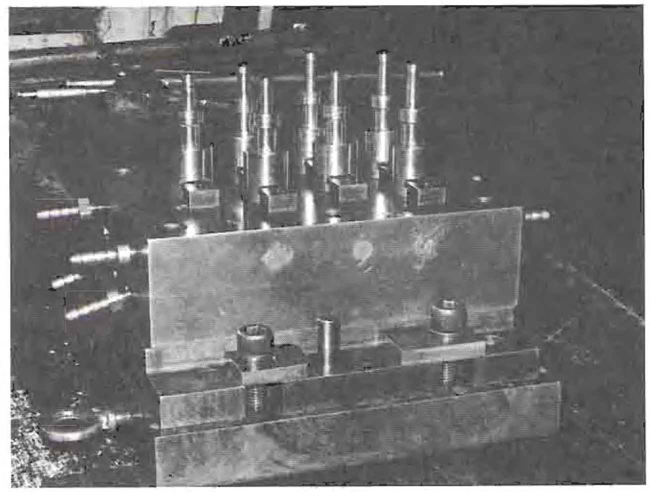


Figure 14: Blank and Cup Die Set

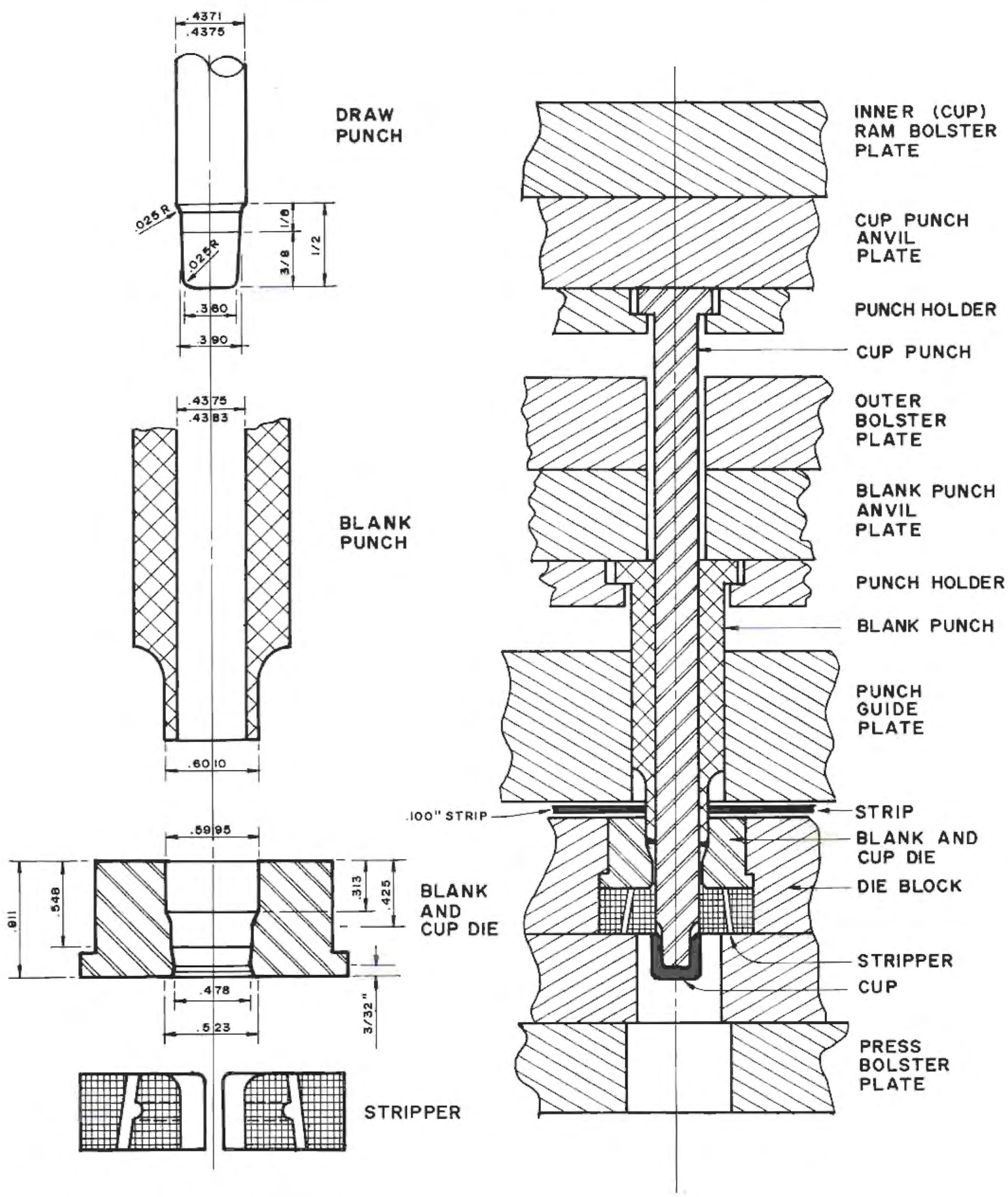


Figure 15: Typical Centerfire Blank and Cup Tools—.22 Hornet Case

Table 2 CASE DRAWING

Typical Metal, Blank, Cup and Draw Dimensions

Caliber	Metal Thickness	Blank Dia.	Cup Dia.	Cup Wt.	1st Draw Dia.	2nd Draw Dia.	3rd Draw Dia.	4th Draw Dia.
.22 LR	.019	.624	.353	12.4	.2470	.2241	———	2 Draw method
.22 LR	.020	.580	.330	11.5	.2241	———		Single Draw method
.30 Carbine	.130	.626	.490	87	.400	.351	———	
.38 Special	.130	.626	.490	87	.434	.415	.3745	———
5.56 NATO (.223 Rem.)	.140	.680	.546	108-114	.479	.4175	.3720	
7.62 NATO (.308 Win.)	.166	.870	.698	214	.597	.534	.462	———
.30-'06	.138	1.020	.763	245	.660	.571	.518	.463
.22 Hornet	.100	.601	.481	62.5	.413	.363	.319	.293

The .30-'06 is bumped after the 2nd draw, and pocketed before heading.

The .38 Special is bumped after the 1st draw.

The .22 Hornet is indented after the 3rd draw.

These examples were chosen from the methods of 3 different makers to show the wide choices possible in drawing cartridge cases as to metal thickness, number of draws, and amount of diameter reduction per draw. Those shells with the fewest draws generally use more than one die per draw, up to 4, in the case of the single draw .22 LR case.

much higher than the theoretical tonnage required, to provide a safety factor as well as to reduce the strain on the press. Since this is a double action press, wherein the inner ram follows the blanking ram to form the cup from the blank, a separate rating for needed press capacity has to be made for the inner ram. The die used for blanking and cupping is a combination, reflecting its dual purpose. The upper end of the die has a cylindrical section with its top edge sharp where it shears the brass against the action of the blanking punch. Lower in the die, a concave radius, blending into a convex radius, molds the brass blank around the cupping punch to form the initial cup. The lower section of the die is constricted to form a narrow land which puts a final size on the cup. Below the land, the die opens out. The punch, with the cup on its end, then passes through a stripping die which expands to let the cup through, then closes around the punch. The stripper then holds back the cup when the punch rises for the next stroke, and the cup goes down the chute or whatever into the work basket. *Figure 14*, shows a typical blank and cup die set.

Clearances between the blank die and the punch increase with metal thickness. The average is about 5% of metal thickness. In any event, clearance is not held to a tight minimum. Small clearance means greater tool wear plus a chance that punch and die might meet, chipping their edges. Further clearance affects to a degree the contour of the top of the cup. Likewise, too sharp a convex radius in the cupping die may cause a ridge on the rim of the cup. In further drawing operations the ridge is apt to be separated as a thin wire ring, which will damage the next case drawn.

The blanking punch is, naturally, ground square across its axis and is as sharp as possible. In order that the cupping punch may center exactly on the blank, the punch is fitted very closely and centrally inside the blank punch. Radius at the lower end of the cup punch cannot be too sharp or the punch will pierce the blank instead of forming it. If too large a radius is allowed, the metal will flow around it, thinning the bottom of the cup. *Figure 15*, shows illustrated drawings for .22 Hornet blank and cup tools.

With multiple punches working on the strip, spacing between punches becomes important. Too much space means wasted strip. Too little means blanks are not cleanly sheared from the strip. The result is poor cups. Beyond this, the die set is designed so that individual dies may be easily replaced when they become worn. Space must be allowed for the die holder between dies, or it will not be strong enough to hold the dies in place. The dies are staggered in the holder so that there is space between dies for strength, yet hole spacing in the strip allows for maximum utilization of metal in the strip. *Figure 16* shows how this is done.

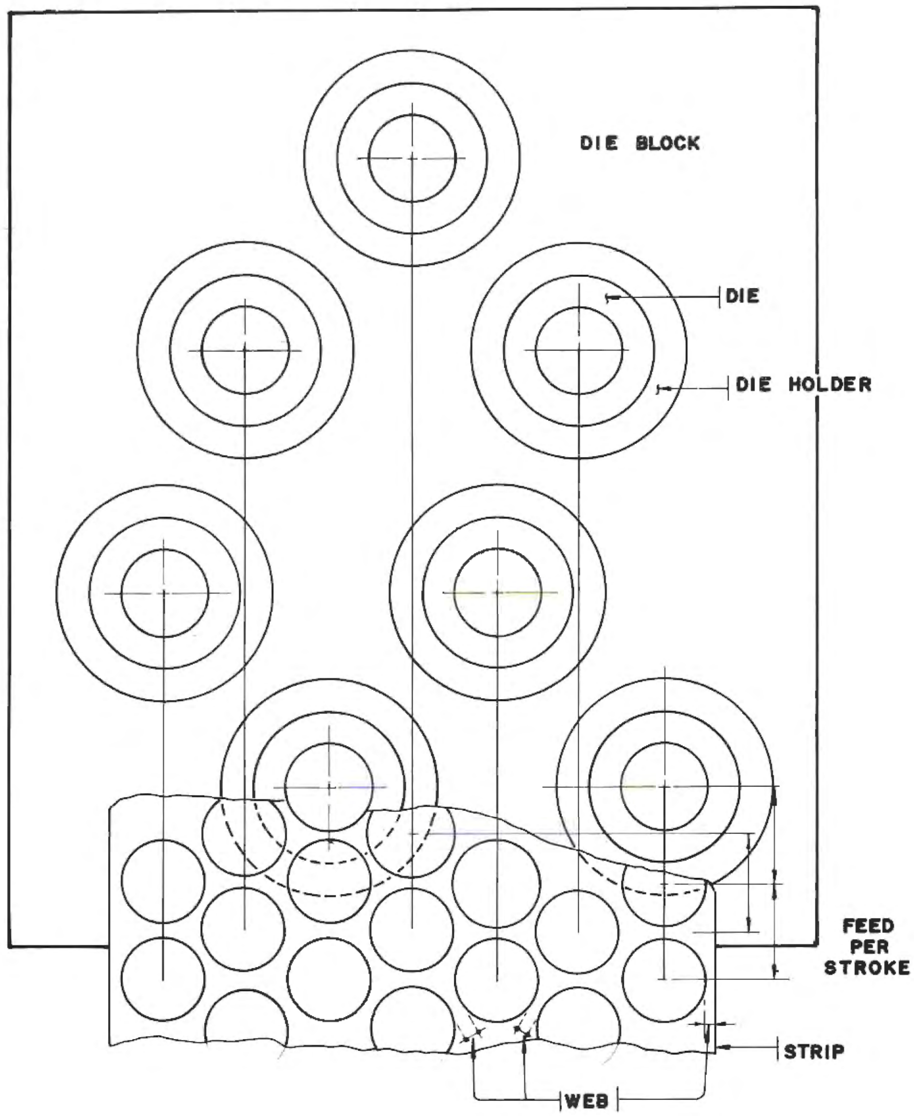


Figure 16: Seven Cup Layout for Blanking Thick Strip

Conventionally, distance between adjacent punchings from the strip is about $\frac{3}{4}$ of the metal thickness, but it may be less. Accuracy of feed of the strip feeder in the press must be equal to or better than this spacing. On a .223 Rem. strip with a thickness of .140″, web spacing is .100″ between dies, and for thickness at the edge of the strip. This makes for a strip efficiency of 64.5%.

Lubricants used in blanking and cupping have long been soap solutions. There are more modern lubricants, sulfonated oils and similar materials. Availability of these newer types depends on local suppliers and the demands of their customers. Soap is the most universally available.

Following cupping, the cups are sent to anneal, followed by a pickle in acid to remove scale, and a wash. Depending on the cup lubricant used, the cups may or may not receive a rinse before entering the annealing furnace.

Annealing and Washing

At various stages in case manufacture, the developing cartridge case becomes too hard to have any further work done on it. It is a characteristic of brass and its crystal structure that cold work, in the form of drawing, bending, or rolling, makes the brass harder, as well as stronger.

A case cup is annealed before the first draw, and between successive draws. Straight cases are not annealed after the final draw. Bottle neck cases are given two special localized anneals later in processing after the final draw.

Work hardened brass, when heated to approximately 530°F, undergoes an immediate change.

Crystals, which have been stretched in one direction and squeezed in another, snap and break up into very small crystals, .005 mm or so in diameter.

On continued heating above the critical temperature, the small crystals begin to join together, forming increasingly larger crystals. The longer the heating the larger the crystals grow. The higher the temperature, the faster they grow.

Brass may become too soft, or the crystals so large they leave a rough "orange peel" surface. Crystal growth is, therefore, kept within a range which allows the case to be further drawn, but which leaves the final drawn hardness where it is needed for strength.

Annealing may be done using either gas or electric heat. It may be done continuously, or in batches. Choice of heat and furnace depends on the quantity of brass to be handled and the type of anneal desired. Cup and draw anneals are handled in large quantities in either a rotating furnace or on a moving belt. Specialized body and mouth anneals will be discussed later.

Because cold worked brass starts recrystallization and grain growth at a lower temperature, the side walls of a drawn case, as with rimfire, are affected sooner than the bottom of the case. Side-wall crystal size is therefore most often used as a basis for control rather than the bottom area. There is no set formula for grain size. Each manufacturer develops his own conditions, depending on the product requirements and the equipment used.

Pickling and washing are carried out as for rimfire cases.

Drawing

There are no basic differences in the first, second, or third draws, except for punch and die sizes. Between each draw, there is an anneal. Following the final draw, there is no anneal as the case wall must be left hard for strength. As to the amount of diameter reduction and draw length increase per draw, there is no set rule. Usually, two dies are in line at each draw, so that the punch passes through both. The first die does most of the work.

Table 3
Dimension Changes

Cup through Finish Draw
7.62 NATO Case

	Outside Dia.	Height	Wall Thickness A	B	C	Bottom Thickness	Annealed Grain Size
Cup	.693	.47	.083	—	—	.166	.080
1st Draw	.597	.85	.059	.048	—	.164	.045
2nd "	.534	1.35	.049	.037	.031	.175	.030
3rd "	.490	1.72	.039	.026	.022	.180	.020
Fin. "	.462	2.65	.040	.029	.021	.185	—

A thickness is ¼" from inside bottom
B " ½" " " "
C " ¾" " " "

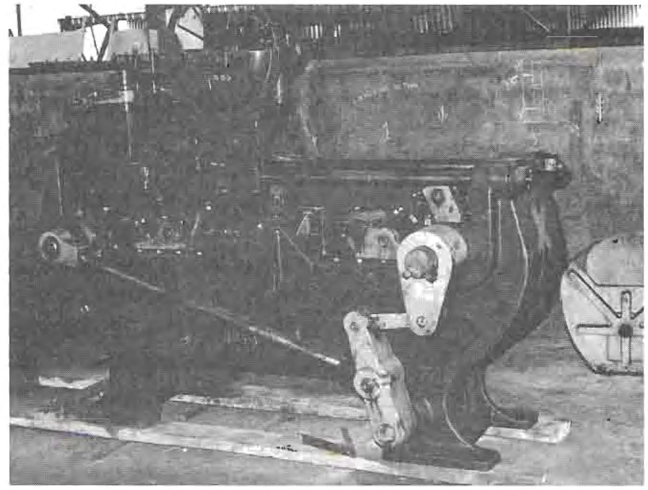


Figure 17: Centerfire Case Heading Press

Figure 18: Centerfire Heading Operation

Table 3., shows the progression on a 7.62 mm NATO case from first through fourth draw. Other calibers and sizes would be roughly proportionate.

Bunting, Pocketing, and Heading

These three operations are lumped together here as they are usually carried out on the same type of machine. The machine used is a larger version of the rimfire heading press with two opposing rams and a central die holder used for heading rimfire (See Figures 17 & 18).

When a cartridge case is drawn from a cup, the end of the case, instead of flattening out, forms into a rounded dome. Before heading, this rounded end needs to be flattened out by bunting, or in some cases, indented, to make it head better later.

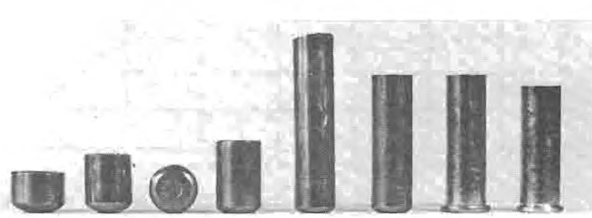


Figure 19: Case Drawing Steps—.38 Spl Case

Either bunted or indented, it is easier to center the pocketing punch on the end of the case. The flattening operation creates additional hardness through cold work. Cases, depending on the manufacturer, may either go on to heading, or in some instances to additional steps, as for instance the .38 Spl , 1st draw, shown in *Figure 19*, which has been bumped.

Indenting adds a deep dimple or a partially formed primer pocket to the case. This increases cold work beyond simple flattening. The additional hardness developed, plus the partially formed pocket, help in making a strong head for use with higher pressure cartridge cases. A .223 Rem. cartridge case used for making rifle proof loads is commonly pocketed before heading. The standard .223 Rem. may be headed directly from the drawn shell without indenting or flattening. Cases for the .30-'06 and 7.62 mm NATO (.308 Win.) are pocketed before heading, as are most other larger rifle cases.

Heading is a more critical operation than pocketing. Several very important dimensions must be maintained. Hardness in several specific points, especially around the primer pocket, must be raised to specified, narrow hardness ranges. The "bridge," the thickness of metal between the bottom of the primer pocket and the inside bottom of the case, is carefully adjusted. Bridge thickness is important; a thin bridge will not support the primer against the firing pin blow. A bridge that is too thick makes piercing the flash hole more difficult. More piercing tools break, and there is down time and production lost in changing tools. A reasonable thickness for the bridge is .055" to .060".

The inside heading punch, unlike the .22 rimfire heading punch, does not have a step against which the mouth of the case rests. The punch is contoured to match the bottom of the case, or to whatever final shape is desired inside. Punch diameter is close to the inside diameter of the shell to give maximum rigidity and support to the case while the outside punch does its work. The inside punch picks up a shell from the feed lips and pushes it through the heading die. The end of the shell is positioned a little outside of the die. Here the punch dwells until heading is complete, then it retracts, leaving the headed shell in the die. The next entering shell pushes the previously headed shell out of the die. An intervening deflector rises briefly as the shell is ejected, keeping the headed shell from striking the advancing outside punch.

The shell is now in place, braced against the coming blow from the outside punch. The outer punch bears the headstamp with its reversed lettering, and the primer pocket tit. The punch forces its way into the soft brass end of the drawn case, mashing it out to form a flange outside the die, impressing the headstamp, and forming the primer pocket. At the same time, the bridge is brought to the proper thickness. This cold work makes the brass very hard around the primer pocket, and makes the rest of the head harder as well. Typical diamond point hardness requirements are shown in *Figure 20*.

The flange on the head is later turned to size if the case is a rimmed one, or removed entirely if the case is rimless. In the meantime, the flange is of use in pulling the shell out of a reducing die, if the case is to be bottlenecked.

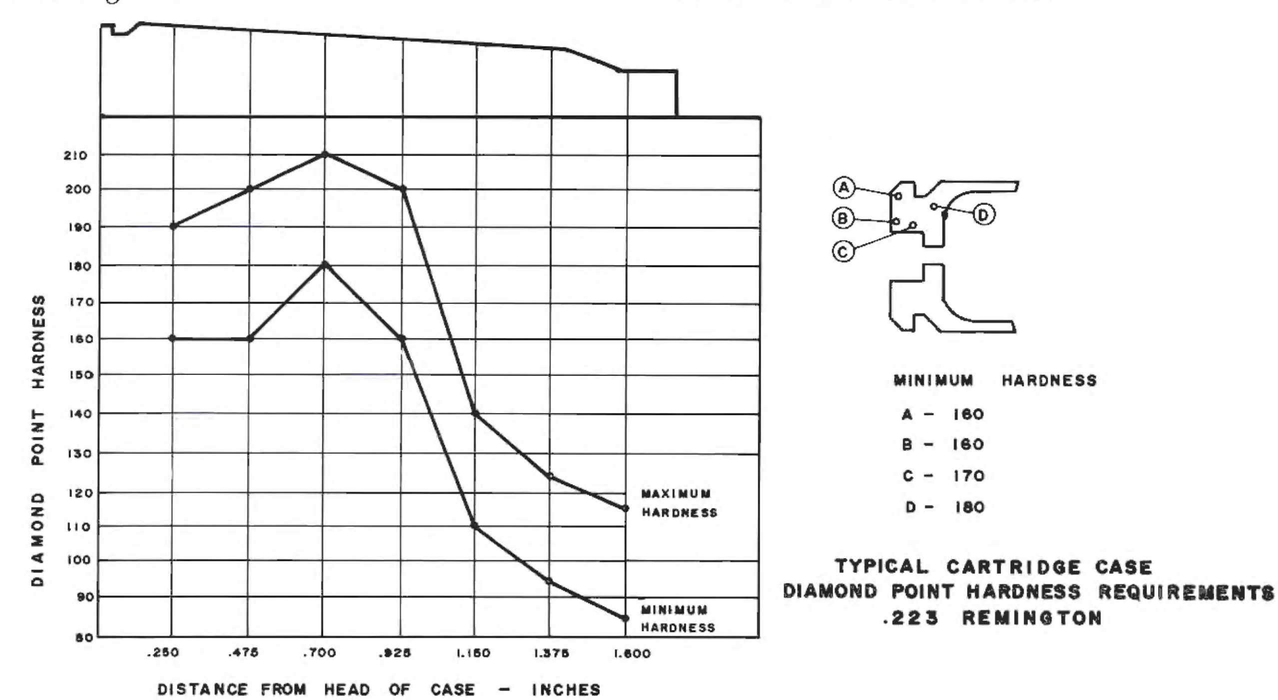


Figure 20

It is necessary that the primer pocket be very carefully controlled as to depth and uniform diameter from top to bottom. Taper either way is bad in the pocket, leading to leaky primers in firing.

A small radius is left at the mouth of the pocket to ease the entry of the primer on the priming machine.

Lettering on the headstamp is distributed around the circumference of the head, so that the pressure of the punch is uniformly applied, and the punch kept well centered.

Since there is no reasonable correction for over- or undersize pockets, gauging during production should be frequent. Plug GO and NO-GO gauges are normally used for diameter, with a dial gauge for depth. Bridge thickness is also checked with a dial gauge, usually against a master.

Headstamp lettering wears and sometimes chips off. Headstamps are checked when primer pockets are checked.

A broken punch means an immediate work stoppage. Finished work is held aside until it has been inspected for damaged pockets.

After heading, straight sided cases go to flash hole piercing or head turning and length trimming operations. The sequence depends on the manufacturer. Bottleneck cases next go to body anneal or to flash hole piercing.

Body Anneal

A drawn case, when tapered, shouldered and necked undergoes additional cold work, which, if a special step is not applied, would leave the wall so hard it might split in firing. At the same time, the final formed shell must be left hard enough and springy enough to expand, to obturate in firing, yet spring back to size for extraction. The head must be left as hard as possible. The answer is to add a localized body anneal, leaving the head hardness unchanged, but softening the sidewalls enough to allow the additional cold work of tapering and necking.

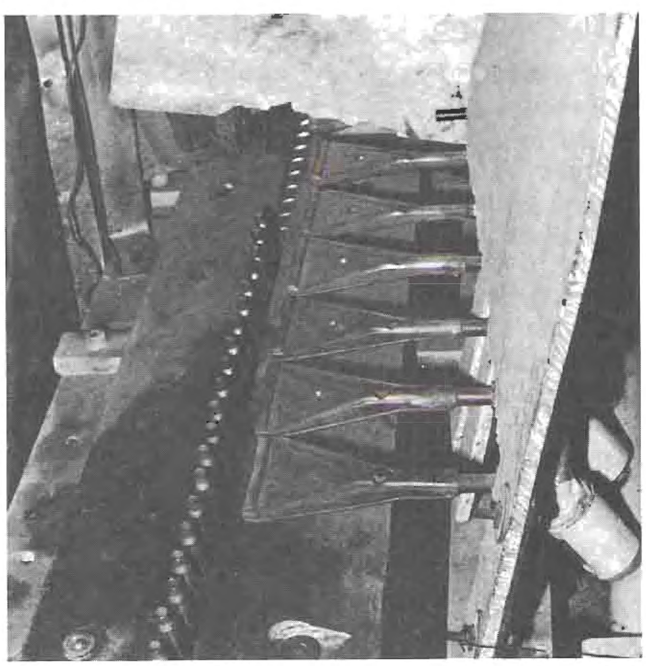


Figure 21: Gas-flame Neck Annealing

The modern way is to body anneal by induction heating. The case, placed upright, passes through a series of coils carrying high frequency current, which in turn induce heat in the area of the shell to be annealed. Only the upper portion of the case is heated. The head is kept below annealing temperature. It is sometimes necessary to have the heads kept cool in a shallow water bath as they pass the induction coils. On leaving the annealing section, the cases fall into a water bath to cool, otherwise retained heat might soften heads.

The older anneal system uses a gas flame. The cases, again upright, run a gauntlet of opposing gas flames, so arranged that they heat the upper portion of the case. Again, the heads may be water cooled in passing. Water is safer than air for cooling.

The anneal may be a straight line affair, the shells being propelled along the flames by a worm or screw (See Fig. 21), or the shells may be set up on a revolving table, to be tipped off into water after anneal.

Body anneal ordinarily brings the case up to dull red heat momentarily in a gas flame. The induction anneal, more accurately controlled, may keep the cases at a lower temperature a little longer. Time and temperature are adjusted either way to reach the desired softness. Over-annealing cannot be compensated for in later processing.

Since most body annealing is done in the presence of air, an oxide film is formed on the case. Due to the softness of the annealed case, the case is not washed or pickled until it has gone through the next process, reducing.

Reducing

This operation may be carried out either in a transfer or a dial press. The body is tapered, the shoulder and neck formed, and the neck sized to final inside dimension.

On a full bottleneck case, reducing is usually in four steps, and four work stations are needed on the press. The first station brings a resizing punch down inside the mouth of the case, bringing it back to full roundness, and even belling it out very slightly. This keeps the metal from closing in unevenly, and possibly folding over, as the neck is formed.

At the next station, a die descends on the case, putting all, or nearly all, the necessary taper on the case. It also starts forming the shoulder and neck. Shoulder length, at this point, must be left

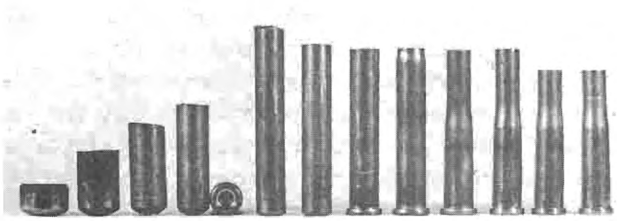


Figure 22

Figure 23

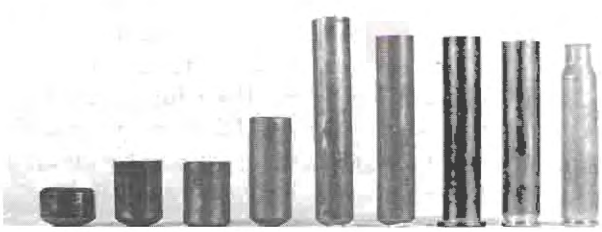


Figure 24

longer than it will be in the finished case. Examples of neck forming are shown in *Figures 22, 23, and 24.*

The third station brings the neck down to size, adjusts shoulder length, and corrects taper in the shoulder area.

The final station sends a punch down the neck to bring the neck to final inside diameter. At this point, the shoulder and neck must be protected against shortening by the push of the sizing punch. This is normally done using a die that covers the shoulder and part of the side wall.

It is on this press that the flange on the head comes in handy. The case is not pushed all the way into the forming dies since the taper does not extend the full length of the case up to the head. In a dial press, the flange drops through a keyhole shaped opening, and is then moved along the keyhole to the smaller diameter end. This locks the case into the dial so that the rising dies on the press leave the case in the dial to be transferred to the next of the four steps.

The case is very lightly oiled in the reducing operation to make it easier to reduce as well as to ease wear on the dies and punches. Care must be taken, however, not to over-oil. Excess oil on the outside of the case will create bubble-like dents where it is confined.

After reducing, the case goes to pickle and wash, flash hole piercing, or head turning, depending on the operation sequence.

Piercing

Piercing may be done on any one of several types of press. Sometimes it is combined with priming, on either a dial press or a transfer press. Either way, the basic principle is the same. An inner hollow punch, matching the inside shape of the head, holds the case in position below the piercing punch. The piercing punch is a two part punch. The outer part of the punch enters the primer pocket to center the inner piercing pin, which follows to pierce the flash hole. The pin acts against the inner punch, shearing the brass through the bridge into the hollow inner punch.

Whenever possible, especially with straight sided cases like the .357 Mag., the pierce is accomplished on the priming machine, followed immediately by a probe which verifies that the flash hole is open. The primer is then seated.

On bottleneck cases, piercing normally precedes body anneal so that a full-size inner punch may be used in the case. This makes it easier to line up the primer pocket with the piercing punch, and an outer case die isn't needed.

Piercing may be from inside out as well as from outside in. Outside-in is the better way, for any burr left in punching will be inside the case, where it cannot interfere with seating the primer to full depth.

The flash hole may be drilled, as it is with Berdan-primed cases. The Berdan primer pocket calls for two small holes to be drilled in the pocket at an angle to each other. Drilling is slower than punching, but makes a very accurately sized, clean hole. Small drills are delicate, more so than a piercing pin. The Boxer primer, of course, only needs the central flash hole.

Head Turning and Trim to Length

It is common practice in Europe to combine these operations on one machine for a long tapered case. In the U.S., two separate operations are more common.

The combined operation sees the case pushed into a rotating die, the inner taper of which matches that of the outside of the case. The case sticks out of both ends of the die. A head turning knife moves in to cut the rim to shape, or to reduce the flange to a rimless shape including the extractor groove. At the same time, a knife moves in to trim the mouth to final overall case length. The trimmed case is pushed back out of the die, to make way for the next case.

On straight-sided cases, the case is head-turned as a separate operation. The case is generally too short to use the double ended system. The case is pushed into a collet, a tool moves in and shapes the head, trimming off the excess flange material produced in heading. A rimless case may be pushed on down the collet shaft by a following case, while

a rimmed case is simply pushed back out.

The case mouth, on either a straight or bottleneck case, may be trimmed differently. The case is held upright between two gripping fingers while a rotary cutter descends and mills off the excess length. Here in Manila, the company purchased some U.S.-made "Black Rock" trimmers of this type. They proved to be equally handy for .38 Spl, .30 Carbine and .223 Rem. Since these were purchased in New England, and didn't come from Winchester, it is not difficult to imagine which ammunition plant they originally came from.

By now all the steps have been taken to produce straight cases except priming. Mouth annealing remains for the bottleneck case.

Mouth Anneal

The reason for mouth anneal – to prevent season cracking – was discussed at the beginning of this chapter (See Fig. 21).

All bottleneck cartridges, military and commercial, are so treated. The military is so particular about the anneal that the discoloration or oxidized film is required to be left on the case as proof that the anneal has been done. On the commercial case the oxide film is removed, again by pickling and washing. The public wants its cases shiny.

As with body anneal, either gas or induction heating may be used. Only the upper end of the case, down to the shoulder, is heated. The extent of the heating shows clearly on a military case. Annealing equipment is essentially the same as for body anneal. The hot zone is simply raised, and time and temperature adjusted carefully.

Primer Seating

One of the most carefully controlled steps in case manufacture is primer seating and crimping (if the case is to be used for military rifle ammunition).

The necessity for close tolerance between primer diameter and primer pocket was mentioned earlier. The fit has to be tight to prevent primer leakage. At the same time, too tight a fit causes mutilation of the primer and probably later misfires. The primer must be seated below flush for safety in handling and loading. The normal figure is .002" to .005" below flush. In addition to safety, the seating to proper depth pushes the anvil up slightly into the mix, increasing sensitivity.

The tooling must fit the primer. The end of the priming punch must neither dent the primer surface, nor compress the middle of the primer.

Accurate centering of the primer over the pocket is also necessary to prevent primer mutilation. The primer feeder, by making sure all primers are right side up, eliminates the chance for a critical defect, an "inverted primer."

Priming can be a hazardous operation. Dry primers, ready to load, are handled in quantity on the machine, which may be using up to 80 or so a minute. Two methods of handling primers on the machine are commonly used. One method puts the primer on a flat tray, beneath a clear plastic cover which keeps them in place without a chance to turn wrong side up. The tray is on a tilt so that primers can feed out the bottom edge into the feeding and loading mechanism. The other method stacks the primers one atop the other in a tall tube, which is loaded in a separate operation and inserted as needed on the priming machine. In either system, the primers are subject to mass explosion.

Since primers are apt to drop small bits of priming during handling, the priming trays, the tubes, and the machines must all be kept scrupulously clean. Even a bit of dust may set off all the primers on the machine.

One method of keeping a primer tray filled with relative safety was developed at Western Cartridge Co., and patented, some years ago. The Western procedure, which is described in detail in the chapter on priming operations, employs a safety-covered, pre-packed paper tray to hold primers for loading into a primer feeder. In use the safety covering—which is also of paper—is removed and replaced with a sliding hold-down plate. The assembly is then placed face down on the feeder and the sliding cover is removed, depositing all the primers, anvil down, on the priming tray. The paper tray is lifted off, leaving the primers in place. The transparent plastic cover is placed over the primers.

Dry primers in bulk should never be poured, tumbled or shaken. A quantity as small as a thousand contains more than an ounce of explosive mix. Flying primers and anvils can cause serious injury, and the mix, if confined, can do deadly damage.

The use of a vibratory type feeder to orient and move the primers into position, if attempted, needs special precautions. The bowl must be strong enough to contain an explosion of whatever amount of primers are placed in it. Cleanliness is a matter of constant concern. Pouring primers into the bowl is dangerous. Even sneaking a peek into the bowl, when it is vibrating, is only a bit more healthy than playing Russian roulette.

For military rifle cartridges, an additional step is required, following seating the primer. The primer is crimped in place, so that even if it loosens in firing, it won't fall out of the pocket to jam the gun's action. In a fully automatic weapon, pressures may rise as the gun heats up. The higher pressures, plus the rough handling the cartridge gets in full-auto actions, sometimes expand primer pockets. The crimp takes care of this.

Some primers are simply staked with three indentations around the pocket circumference. Other primers are crimped by a full circular closing in of

the case around the pocket. Either way is satisfactory. Care must be taken not to further crush the primer or misfires may result. Crimping is frequently done immediately after primer seating at another station on the same machine.

A second step after priming is common to both military cartridges and some production of sporting ammunition. The annular joint between primer and primer cup is filled with a lacquer which seals the gap against penetration of oil or water. This operation is also usually carried out on the same machine. In one method, a needle dips into a lacquer reservoir, picks up a drop of lacquer, and transfers it to the primer annulus. The surface tension of the lacquer spreads the drop uniformly around the primer. Colored lacquer is used, so that the oilproofing is visible.

Mouth Waterproofing

Military rifle cartridges are further protected against oil or water by having the case mouth coated with an asphaltic type of material, deposited in a thin layer in a solvent. This step is performed several hours before loading, so that the coating is still slightly sticky and plastic. The bullet, as it is seated, pushes the coating down the neck of the case, leaving a ring of material solidly against the base or boattail of the bullet. The seal is checked on sample cartridges by immersing the cartridges in water and soaking over night, followed by shooting for pressures and velocities. A drop in pressure and velocity beyond normal variation indicates leakage.

A faster alternative method is to put the ammunition in a bell jar under water, and apply a vacuum of 10" to 14" of mercury. If more than two or three bubbles from a sample of ten rise to the surface in a specified time period – about 15 seconds, the sample indicates leakages. Rejection or acceptance is a matter of the applicable military specifications.

With the application of the mouth waterproofing, the cases are ready for loading. Commercial cases have already gone on their way.

CHAPTER III
THE BULLET

Some Background

Taking the simplest view, a bullet is a vehicle for delivering and applying energy to a point distant from the shooter. To a target shooter, application of energy to pierce the paper target doesn't amount to much. Getting to the distant, precise target center is all important. The hunter is more fussy about what the bullet does with its energy, so is the peace officer. A great deal of work has gone into the ways and means of making the bullet do its job. Some efforts have been simply to make the bullet look more appealing. Most have been honest efforts to satisfy the demands of the user. Not easy, considering the wide differences of opinion as to what is satisfactory, as well as the breadth of conditions under which the bullet is called upon to perform.

These things can be said about .22 cal. bullets, about lead and semi-jacketed pistol and revolver bullets, and about jacketed, high-power rifle bullets.

It is, maybe, somewhat of an anomaly that a Hague Convention carried an agreement not to use expanding, and therefore more lethal, bullets in warfare, while police today are more and more leaning toward hollow-point and soft-point bullets. Lighter, higher velocity, jacketed, expanding bullets, as well as soft-point and hollow-point loadings in standard bullet weights are increasingly popular in all "police calibers." New game bullets in the revolver magnum calibers are, of course, popular with the hunting enthusiast.

In the last 10 to 15 years, the variety of pistol and revolver loadings offered has about doubled.

There have been changes in rifle bullets as well, beyond the addition of new calibers. Still, the soft-point, in its variations, stays the most popular. The high velocity Open Point Expanding, once popular in .270 Win., .30-'06, and other higher velocity rifle loads, has disappeared from Winchester and Remington catalogues.

Essentially, the newer high velocity bullets of special design other than soft point have the advantage of less point damage in handling and loading, and, with a sharp point, better remaining velocities. These bullets are more complicated to assemble than soft points and may be a little more troublesome in meeting tight accuracy standards.

The boattail, it is generally considered, doesn't add much to the scene if the bullet is traveling well above the velocity of sound. Boattailing, streamlining in other words, helps at the transition stage from sonic to sub-sonic velocity, and at sub-sonic velocities. There are other advantages to boat tailing though. Boat tailing moves the bullet center of gravity forward, a help in keeping a bullet stable in flight. Boattails also reduce the lengths of jackets in contact with the bore, reducing bore friction. It must be remembered, however, that too short a bearing length leads to wobble as the bullet travels down the barrel, creating more yaw at bullet exit and adding to dispersion at the target because of it.

The 5.56 mm. M193 military bullet, for example,

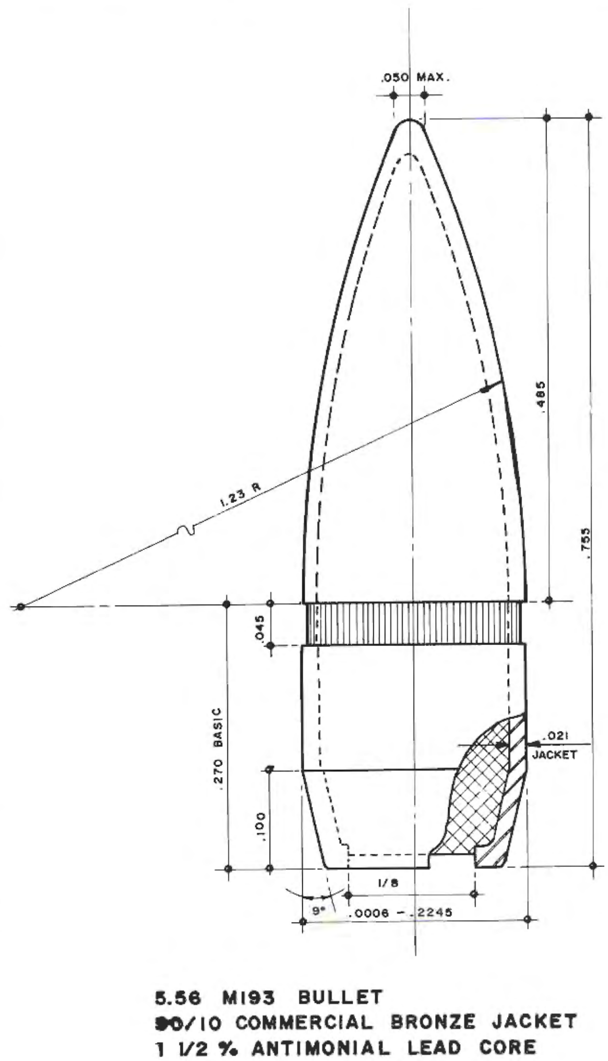


Figure 25: U.S. Government 5.56 mm, M193 Bullet

has a bearing length between the boattail and ogive of only .170" versus a diameter of .2245". Even the bearing of the bullet on the lands is only a little more than one caliber (a length equal to 1 × the bore diameter), about .232". Only a stiff, thick jacket keeps it going straight, and accuracy usually isn't much to brag about. In many things mechanical, a bearing length of two diameters is considered necessary to prevent binding, a simple version of wobble with a bullet. Military specifications for accuracy call for a maximum of 2 inch mean radius at 200 yards with the 5.56 mm. The results frequently run near to that. At the same time, this particular bullet, with its long 5.5 caliber ogive (See Fig. 25) tends to tumble immediately on striking.

I was fortunate enough to have been working between sales and the factory and research when, in the late 1940s, the Silvertip bullet was developed. It was felt there was a need for a bullet that would open as well as a soft point over a wide range of velocities, yet would keep its nose shape under recoil in the magazine, and during firing. The bullet was supposed to penetrate the skin of a game animal and the outer layers of muscle tissues before opening fully. In other words, the Silvertip gave "controlled expansion."

The Sales Department managers, after reviewing consumer correspondence, consulting with hunters and guides, and talking with the salesmen and any other knowledgeable source available, came up with a recommended maximum game range for each caliber to be considered and for each projected bullet weight, as well as for the usual game hunted with that caliber and bullet weight. The "game range" was the longest range over which the bullet could normally be expected to perform with some degree of satisfaction.

Similarly, a limit was set for the minimum range, beyond which the bullet should not disintegrate or separate core from jacket. At distances less than the minimum range, a bullet might occasionally disintegrate or come apart, due to its velocity.

The list of calibers started was about as follows, as I remember it:

.257 Roberts	100-gr.
.270 Win.	130-gr.
.30-'06	150-, 180- and 220-gr.
.30-40 Krag	150- and 180-gr.
.300 Savage	150- and 180-gr.
.300 H & H Mag.	150-, 180- and 220-gr.
.30-30 Win.	170-gr.
.32 Win. Spl	170-gr.
.35 Rem.	200-gr.
.375 H & H Mag.	270- and 300-gr.

Remaining velocities at each of the maximum game ranges for each bullet weight were deter-

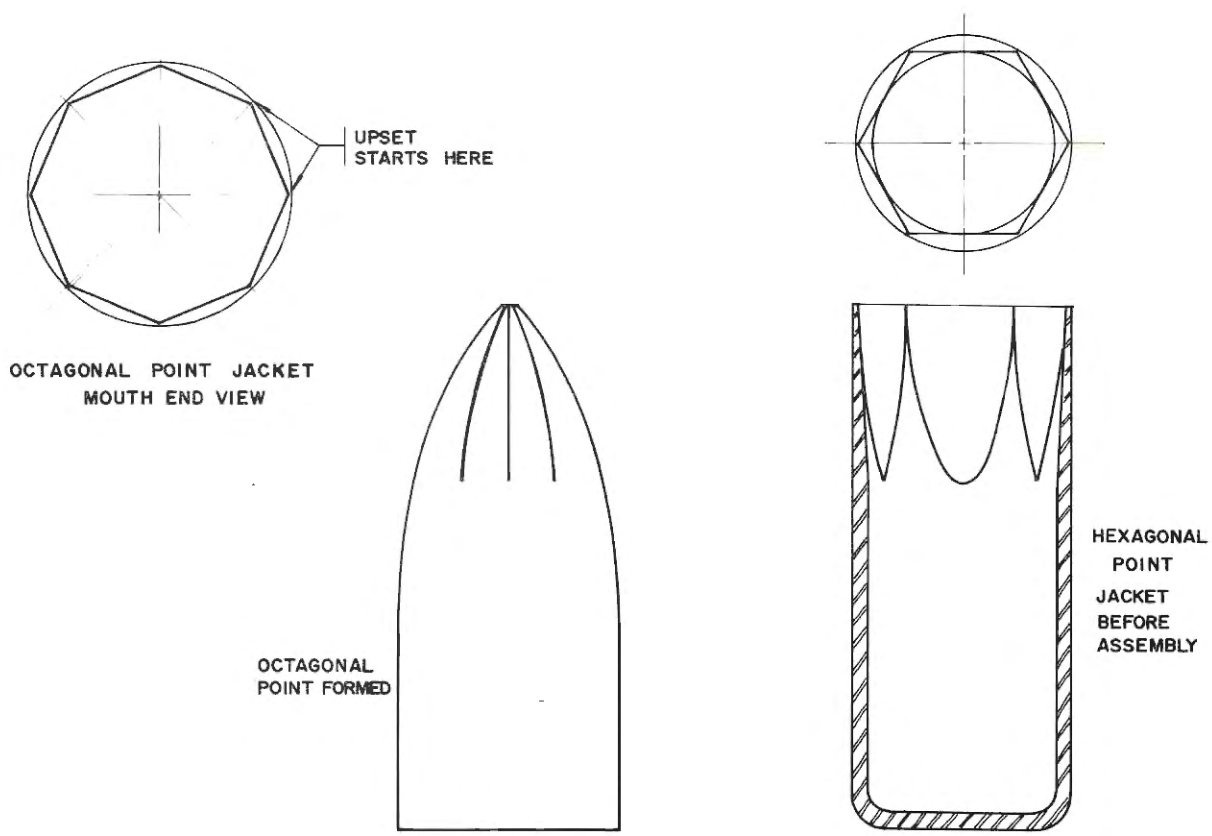


Figure 26: Six- and Eight-segment Expansion-control Bullet Point Serrations

mined. Bullet shape was considered and a choice made as to ogive and shape of point. The .30-30 and .32 Spl had to have the customary flat points for use in tubular magazines.

The first bullets started on were the various pointed calibers, since they had generally the same diameters and weights. This reduced the number of samples, since, for instance, a bullet that would open up at the 300-yd., .30-'06 velocity would also be expected to do so for the .300 H & H at nearly the same velocity at 400 yds.

The protective light metal tip was a natural choice for point treatment. Just who thought up the "Silvertip" designation and the use of a silver colored metal to match, I have forgotten, unfortunately. Anyway, cupro-nickel, nickel-plated gilding metal, and aluminum were all used at one time or another. All worked.

Preliminary samples of .30 cal. bullets were made up, using the ammunition engineers' best guesses as to jacket thickness, tip exposure, tip-metal thickness, and final shape.

These samples were shot into water. As might be expected, the initial results were not entirely uniform. Some bullets expanded too much, some not enough, and some cores and jackets separated.

In an effort to make opening uniform, an 8-sided punch was used to create deliberately weakened segments at the tip. This made the bullet open into neat strips. (See Fig. 26.) This process was, not surprisingly, called "octagonization." Cores still had a tendency towards what was called "incipient bananafication." The core sometimes moved out like a banana from its peel, but didn't always leave the jacket.

This situation called for a harder core and more tip exposure. By trial and error, until water results looked good, various changes were made. Then changes of knurl were added to fit the various calibers and loadings. Of course, test ammunition was loaded to simulate remaining velocity at the maximum chosen game range for each caliber.

Water results – mostly good, some not so good – led to further adjustments in jacket and mouth thickness. Good uniformity was reached.

Then came the outdoor trials. Arrangements were made with a local packing plant to shoot some "canner" cattle, old cattle only good for use in canned meat products. The company arranged to pay for all damaged unusable meat.

Two riflemen shot one round each into the animal's "boiler room" section, while a third rifleman followed with a shot through the head. The animal was then immediately butchered, the wound damage assessed, and the bullets recovered if possible.

After all the preliminary testing had been done, it took very few outdoor tests to confirm the general utility of the .30 cal. Silvertip bullets.

Results were extrapolated to larger and smaller calibers, and similar development work, less the cattle test, produced the rest of the calibers.

Only minor changes were necessary through the entire .30 cal. line, from .300 Savage through .300 H & H Mag. This was before the days of the .308 Win. and the new magnum calibers.

In comparing today's bullets with those of 40 or more years ago, basics haven't changed much. Refinement has been more the order. Average accuracy has probably improved, as have upset characteristics. Competition from the reloading component makers has been keen. The handloader has become more critical, particularly with the extensive use of rifle scopes and the growing awareness of good bullet performance. The manufacturers have had to keep up.

With lead bullets, velocity and range are limited. Production requires much less finesse than that needed to meet the exacting demands placed upon a higher velocity jacketed bullet.

As will be discussed in the chapters on accuracy and on .22 rimfire match ammunition, the things that make for accuracy start with uniformity, whether the bullet is lead or jacketed. This means uniformity in every step.

Pure lead is not used for lead bullets. It is too soft, damages too easily in handling and loading. Soft lead also upsets in the barrel when fired, losing both point and base shape. Pure lead is seldom used for bullet cores, again because it is too easily damaged and is more apt to separate from the jacket upon bullet expansion at the target. One answer to this is the dual core system. The base portion of the core is hard lead. On top of the base core a second dose of soft lead in the molten state creates a physical joint so that the two pieces of core hold together. The hard core at the rear keeps the bullet and jacket together. The soft lead at the front makes expansion easier.

Antimony is the usual hardening agent in the lead alloy. Antimony content may run from 1% up to 4- or 5%. .22 rimfire bullets from various manufacturers run from ¾% up to about 2% antimony. 1¾% is a reasonable choice. A common core alloy runs 1½% antimony and works well in many bullets.

Tin-lead alloy has also been used for .22 rimfire bullets, and does make a good bullet. The percentage of tin needed to equal antimony hardness is about 4-5% tin vs. 1-1½% antimony. Because tin costs much more than antimony, and requires greater quantities of material to get the same result, it is not a good choice for hardening lead alloys.

No other metal, ordinarily available, works as well as antimony in hardening lead for bullets. Zinc and lead are not compatible. We found this out the hard way at Squires-Bingham.

As part of our operations in Manila, we once did considerable zinc die casting. The die casting

machines were set up near the extrusion press, which was used for making lead wire for bullets. There was no problem as long as we were using virgin metal in both the die casting machine and on the lead extruder. However, the time came when rejected castings and fin and gate scrap went into the die casting pot for recasting. Nobody ever admitted knowing how lead scrap got mixed with zinc scrap, but the nice shiny zinc die castings in one whole run simply fell apart six months or so later. On analysis, a small percentage of lead showed up in the flawed castings. The castings were replaced for the unhappy customer. The lead press went to an entirely different building. Another example of Finagle's Law of Perversity: If something *can* go wrong, it *will* go wrong and it will do so at the most inopportune moment.

Zinc, if it gets into the lead pot, should be quickly spotted. Being of lower density, zinc will float on top of the lead and can be picked out before it melts. The maximum amount of zinc that can be alloyed with lead is about 2%, and the resulting alloy is not much harder than lead itself. If zinc did melt, any amount beyond the 2% level would simply float on top of the lead to contaminate any more lead added to the pot. Stirring the zinc in would make a mixture without strength. Avoid zinc.

Lead Bullets

In a large commercial operation, bullets are not cast. They are produced in a press. All such bullets start from extruded lead wire. Wire is either extruded cold or hot. It is extruded to size, or may be further drawn to smaller suitable size. Wire extrusion may start with a cold billet, or the extrusion press may be charged with molten lead, and the wire extruded while the lead is still hot. Hot extrusion requires less pressure.

Extrusion

The extrusion press is hydraulic. Unit pressure required to extrude lead is from about 30,000 psi for pure lead to 50,000 psi for 3-4% antimonial lead. For a 4"-diam. lead billet, press capacity should be at least 350 to 400 tons.

For cold extrusion, the process starts with a cast, round billet of lead having the proper antimony content. Casting is done vertically, so that any impurities rise to the top as slag. The lead in the mold solidifies from the outside in, of course. Since lead shrinks on cooling, a "pipe" appears in the center of the billet. The caster keeps the "pipe" full of molten lead until the whole billet solidifies. In order to make full use of the caster's time, a series of molds are arranged at the ends of spokes on a horizontal wheel-like arrangement. Rotating the wheel brings each mold in turn to the pouring spout of the lead furnace.

Billet diameter is naturally determined by the press tonnage available. It is an advantage, of course, to use the largest diameter possible to save down time in re-charging the extrusion press.

It is customary to cut off the upper end of the billet, where the impurities are concentrated, so that only clean lead is extruded. The cut-off piece of lead goes back to the melting pot, so that nothing is lost. One method of cutting-off is to have a guillotine-like shear mounted on the press itself, so that as the ram descends, extruding the billet into wire, it is at the same time shearing a fresh billet for the next charging.

Presses may be vertical or horizontal. The wire comes out the lower end of the chamber like toothpaste from a tube, hot to the touch from the extrusion energy.

What happens to the wire next is a matter of choice. Some plants simply coil the wire in convenient sized coils, and it is fed to the bullet or core swagers from the coil. Other plants run the wire through a separate clipper, which chops the wire into short cylinders of suitable weight. These are then lubricated by tumbling, and go to the swaging machine hopper.

One clever method takes the wire just as it emerges from the press and pushes it through a pair of cutting wheels which pinch off the wire into appropriate lengths (See Fig. 27).

Force to operate the pinch-off wheels comes from the thrust of the extruded wire itself.

The usual lubricants used in pressing bullets are a combination of graphite and oils or grease. Without lubrication, particularly with .22 rimfire bullets, the bullets tend to stick in the nose punch in the bullet press. Tools are apt to break when this happens, as a bullet on the punch and a slug in the die at the same time add up to more lead than the die is meant to hold. At the least, the resulting bullet will be laminated in two different places, and will fall apart sometime later. Bad, if it happens in firing a loaded round.

Speaking of lamination, each time a billet is changed in cold pressing, the first several feet of wire from the press are discarded and go back to the melting pot. There is apt to be a lamination where the new lead meets the old. The ram, on some presses, has a retaining dovetail slot cut across its face so that the tag end of the billet is brought out of the chamber, to be melted down and the lead reused. Only fresh lead from the next billet is then extruded except for the first few feet mentioned above.

Here in Manila, the bullet machines operate with wire rather than slugs. Rimfire bullets sticking in punches used to be a problem in spite of a liberal dosage of oily lubricant. This was solved by deliberately oxidizing the wire surface before putting the coil on the bullet press. Time permitting, a

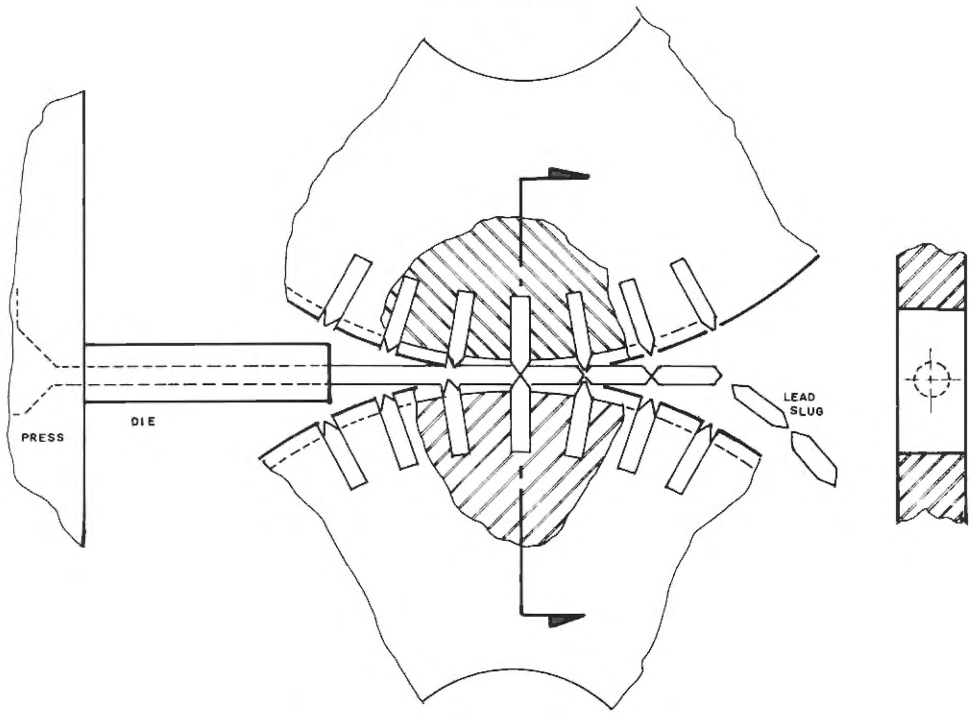


Figure 27: Rotary Slug Cutter for .22 Rimfire Bullet Making

simple soaking in the local water for a day or two did the job. Things could be sped up by adding a small amount of an oxidizer to the water. The oxide film held a little more oil than the bare, bright lead surface. An oxidized surface is also less apt to stick to another surface. At any rate, the sticking stopped.

Bullet Forming

A dial-type feed is usually used for bulletmaking presses. The dial indexes one step at each revolution of the vertical press. Holes in the dial, one for each index step, receive a slug either fed from a hopper or sheared from the wire. The first punch roughly forms the bullet. The dial then carries the slug under the second punch which finishes forming the bullet to shape and weight, then carries the bullet to the final station where a third punch pushes the bullet out of the die.

The slug always weighs more than the finished bullet. A weep hole about 1/32" in diameter in the side of the die allows the excess lead to be extruded. This insures a fully formed, constant-weight bullet or core.

Some use is made of simple horizontal cold heading presses where bullet or core is formed in one step from a slug sheared from wire on the machine.

As the bullets come off the forming machine, they are unknurled. In most factories .22 rimfire bullets go to the loading machine unknurled, and the knurl is added at the crimper, followed by later lubrication. Some European manufacturers knurl .22 cal. bullets before loading.

Centerfire lead bullets are knurled in a separate operation, then lubricated and forced through a final sizing die. Knurling must be slightly deeper than the expected maximum height of rifling in the barrel.

A common knurling machine feeds the bullets base down on a flat dial which carries them around to the knurl section. A drive wheel, with raised knurling in one or more bands on its surface, rolls the bullets past an arced section where the bullet is both knurled and sized, since knurling displaces lead and changes bullet diameter.

Bullet tooling usually consists of three main parts: a die, a top punch, and a bottom punch. The bottom punch usually doubles as the ejector, pushing the formed bullet from the die. The top punch forms the bullet nose.

Tooling for a .22 rimfire bullet looks like that shown in *Figure 28*.

Weight may be adjusted by moving top punch farther up or down, but this will vary loaded length of the bullet. It is better to vary the length of the heel portion by adjusting the height of the bottom punch.

Tools should be made which duplicate the point shape accurately, so that adjustment for weight is kept to a minimum. Weight of .22 rimfire bullets should be kept within .2 gr. variation for regular bullets, and .1 gr. for match.

Rimfire hollow-point bullets are made by two

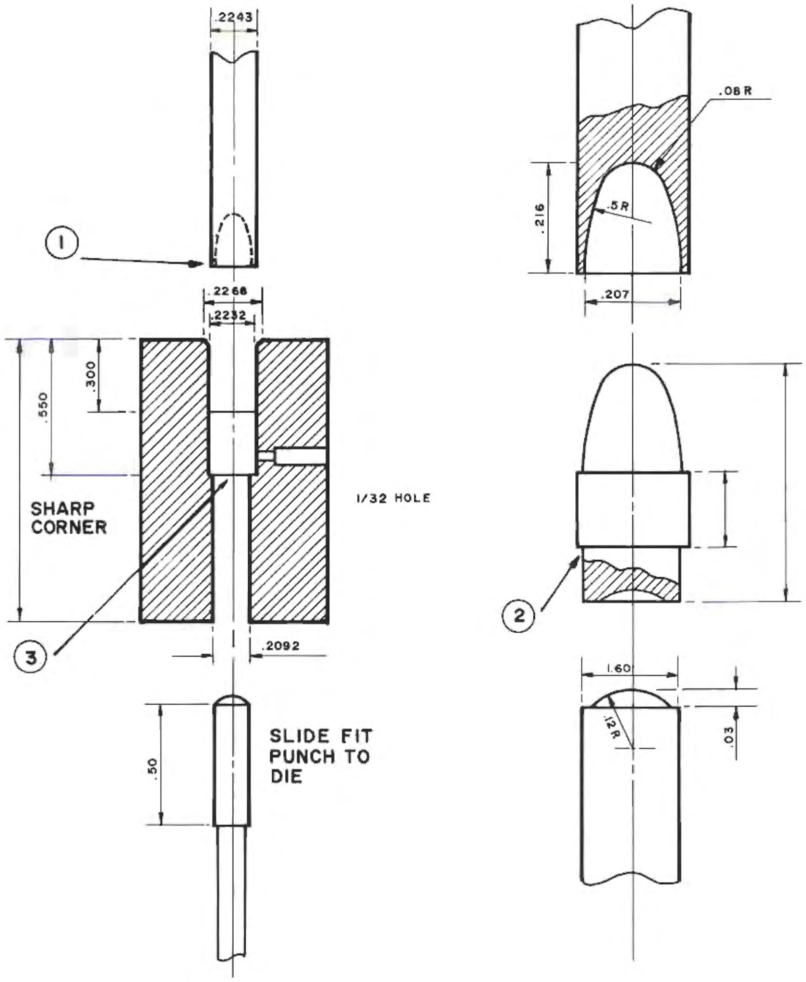


Figure 28: .22 LR Bullet Making Punch and Die Showing Relation to Finished Bullet

Notes:

(1) Most punches break here; edge must be kept as thin as possible to keep shoulder narrow, but thick enough to stand the heavy strain.

(2) Diameter of body and diameter of heel must be perfectly concentric for good accuracy.

(3) Punch must fit die closely or heel will have flash, which will spoil accuracy.

different methods.

The simplest method consists of including a small fixed inner punch at the end of the bullet pointing tool. This leaves a cavity in the bullet nose as it is formed. This hollow-point does not have as large a hollow as the second method.

The second method uses a starting punch to create a cavity in a partially formed bullet. A final shaping punch partially closes the cavity while forming the nose (See Fig. 29).

Bullets to be plated should be formed undersize by about the thickness of the plating. Excessive sizing of a plated bullet, as it is loaded, may damage the plating. Bullets, except .22 rimfire, should be knurled before plating (See Fig. 30).

Bullet plating may be either copper or brass, depending on the manufacturer's choice. Barrel, or tumble-plating is the accepted method. The barrel should rotate slowly to minimize damage to the bullets. Standard plating solution and methods are used for either brass or copper. Either metal is acceptable for plating .22 rimfire bullets, serving as both a partial lubricant and a preventer of leading. It is of prime importance that bullet surface must be entirely clean before plating, so that no flaking will occur in later handling, loading and shooting.

Even with plating, some lubrication of bullets is necessary.

Lubricants

The factory lubricating and sizing machines in many cases duplicate almost exactly the actions of

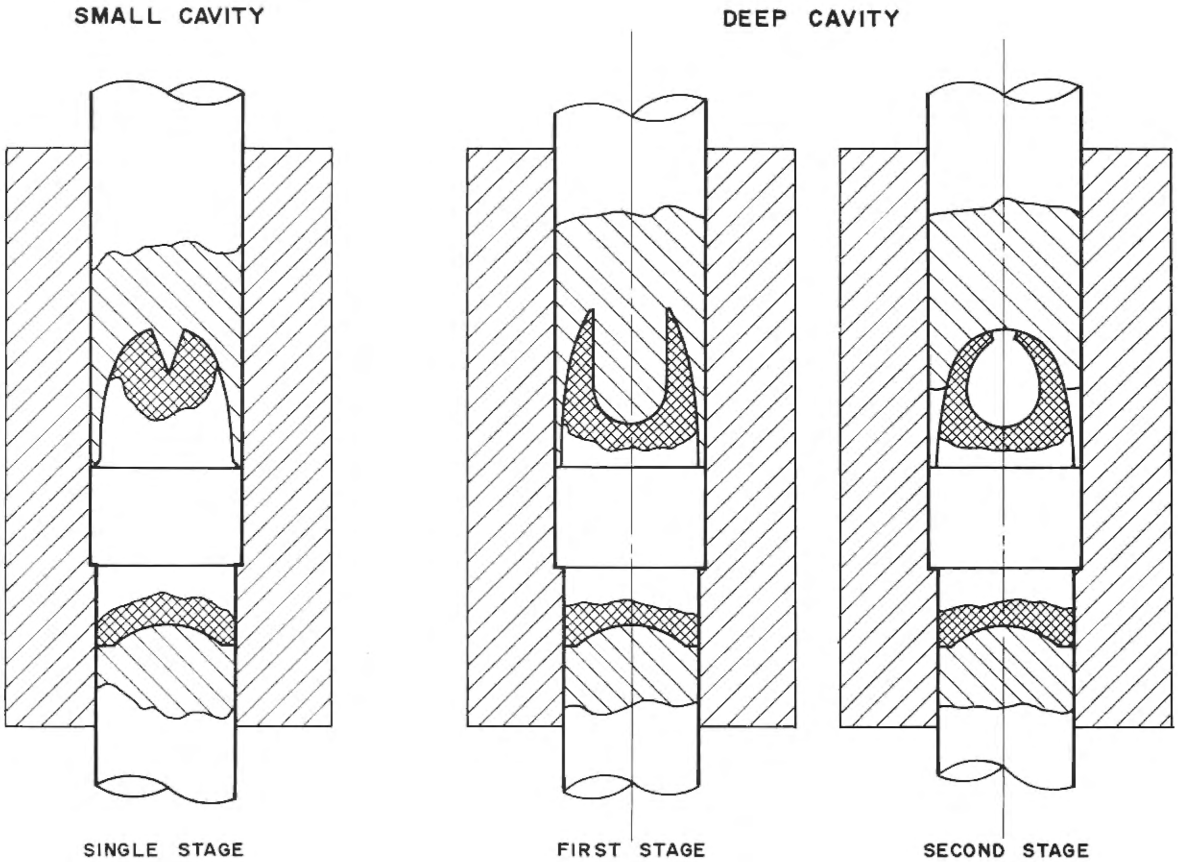


Figure 29: .22 Rimfire Hollow-point Bullet Forming

Figure 30: Knurling .22 Rimfire Bullets

the handloader's cast bullet sizer and lubricator, except that feed and action is automatic.

The bullet is positioned over the bottom pin, the top pin comes down forcing the bullet into the die. As maximum depth in the die is reached, a small tweak of the lubricant screw forces lubricant into the knurl on the bullet. The top and bottom punches rise, bringing the bullet up, out of the die, where it is pushed out of the way to make room for the next bullet.

The qualities for internal and external bullet lubricants differ slightly, as shown in the following list. Internal lubricants are used on centerfire bullets, where grease grooves provided by knurling are hidden inside the case. External lubricants are used on lead bullets for .22 rimfire ammunition.

Lubricant Qualities

1. Must lubricate to prevent metal fouling of bore.
2. Must not contaminate powder or primer.
3. Not greasy or sticky.
4. Transparent, clear, non-staining.
5. Non-reactive with lead or copper plating.
6. Must not leave solid deposits in the barrel.
7. Must not leave corrosive products in barrel.
8. Must be chemically stable.
9. Must adhere to the surface.
10. Must be applicable in thin coatings.
11. Must be easy to handle and apply.
12. Must be non-poisonous.
13. Must be free of offensive odor.
14. Should be inexpensive.

Internal lubricants may be greasy or sticky, do not need to be transparent, and are not applied in thin coatings.

The best lubricants for centerfire bullets are of the waxy or heavy grease type. Above all, the lubricant must not be compounded with a low viscosity oil. Under hot or warm storage, the oil tends to get restless and creep into powder and primer and cause squibs and misfires.

Rather than going through the laborious process of compounding one's own special lubricant, it is probably better to approach one of the oil companies and consult with them on available greases.

Beeswax continues to be a valued component of many lubricants, providing a reasonably high melting point base, with no hint of free oil in it. It is quite expensive.

Carnauba wax is a very hard wax, commonly used in automobile or floor wax, and shoe polish mixtures. It is also expensive. It is usually not used as a lubricant without being modified somewhat by a softer wax. In solvent application, waxes of the carnauba type, dissolved in trichloroethane or similar solvent, may be applied in a thin coat to a plated bullet. This gives a good non-fouling combination, and is dry and non-sticky to the touch.

Ceresin wax and paraffin by themselves do not make very good lubricants. They have a tendency not to stick to the bullet surface. Neither does paraffin lubricate well. Ceresin, however, may extend the use of the more expensive waxes.

Several U.S. companies offer various lubricating waxes, mostly synthetic. These should be explored.

The higher alcohols, dodecanol for instance, may be considered, as may other similar long chain organics, including esters.

Any lubricant which leaves a solid deposit other than its original composition in the barrel should be avoided. Metallic soaps, such as are used in high pressure gear lubricants, are not suitable.

External lubricants, as for .22 rimfire bullets, may be applied hot or with solvent application. This is covered in the chapter on loading and packing.

After lubrication, lead bullets are delivered to loading. Lubricated bullets should be protected from air-borne dust.

Jacketed Bullets

Cores

The core for a jacketed bullet is made the same way as a lead bullet is made.

Lead, pure or antimonial, depending on use, is extruded into wire. Wire may be fed to the forming press in coils, or it may first be cut into slugs to be fed to the forming press. After forming, the cores are washed in a tumbler with mild action, dried, and sent to bullet assembly. Cores must be clean and free of any lubricant.

Choice of core shape is up to the manufacturer. Some makers with large caliber bullets use a plain cylindrical shape. The advantage of a plain cylinder is that it can be fed either end up. Not so with shaped cores. Most soft-point and hollow-point bullets can be made with a cylinder core.

With full jacketed bullets, especially those with long ogives, the core is formed so as to fit the inner ogive fairly closely. But not too closely. Some provision has to be made for escape of air trapped between core and jacket. The core for the 5.56 mm M193 bullet is a case in point (See Fig. 31).

The tit at the end of the core fills the bullet jacket tip first. The core then expands under the pressure of the punch, so that air escapes to the rear.

Speer has an excellent process of pouring the core at the point of soft-point bullet assembly. By an addition to the machine, a hard partial core is first poured, followed by a softer lead topping to give a two-part core with the two parts, being molten, fused together on cooling.

Core-antimony content may run from 0% to 2% or more. The hardness to resist deformation of soft points in handling and loading has to be balanced against resistance to expansion in game.

Jackets

Jacketed rifle bullets use either 90/10 commercial bronze or 95/5 gilding metal for jackets. Fouling is minimal; the metal is easy to draw. The 90/10

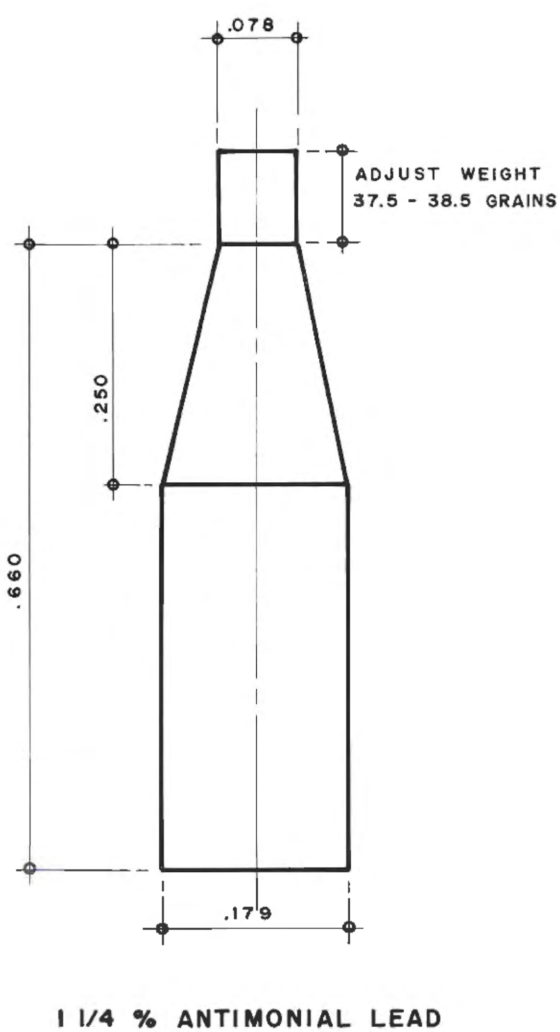


Figure 31: 5.56 mm M193 Bullet Core

material is stronger than the gilding metal 95/5, and resists upset in the bore better. Using 90/10 metal allows jackets for a given caliber to be slightly thinner, saving on material cost.

Jacket making follows the same basic steps as case making, up to a point. Steps are:

Blank and cup
Anneal, pickle and wash
Draw, once or twice
Wash
Trim

Soft-point, hollow-point, and other specially-pointed bullet jackets stop here. For full metal jackets, the next step (6) is pointing, which is done in one or two steps.

Normally, it is not necessary to anneal between draws or before pointing, although it may be done if a softer jacket is wanted.

The punch on the final draw may be tapered so as to vary metal thickness in the side wall, thinning the metal at the mouth of the jacket. When the bullet is formed, the metal in the ogive is thickened as it is reduced in diameter. Hence the tapering, so that jacket metal at the open end of the soft point bullet does not become too thick to upset.

Special shapes, including flats ground on the punch in the tapered portion, provide thinned and weakened lines which promote reliable expansion. Speer's Pento-point is an example. Six- and eight-sided punches have been so made and used (See Fig. 26).

The jacket is commonly trimmed in a trimming lathe. A collet receives the jacket, positioned by a push rod acting through the feeder. A knife moves in and trims the jacket to length. The following jacket pushes the trimmed jacket down the hollow head stock shaft to fall into the work box. The trim falls into the catch box below the trim knife.

Alternatively, by increasing the draw punch diameter at the proper length until it is almost the size of the die, the jacket gets pinched off as the punch moves into the die. This is called "pinch trimming." The trimmed edge isn't quite so neat as a lathe-trimmed jacket, but the finish is fairly good. The advantage is one of cost. A separate trimming operation and its required machine are not needed. The same system, incidentally, is used on some .22 rimfire cases, and on various other case draws. Two strippers are needed, one to strip the drawn jacket from the punch after it has gone through the die, the other to strip the trimmed portion from the punch as it comes back out of the die.

Figure 32: Jacketed Bullet Assembly

Lubricants used for drawing jackets are essentially the same as those used for drawing cartridge cases. A good quality soap, such as Ivory, still is one of the best lubricants available, although there are more modern types – special oils and similar things – which are coming more and more into use. Again, the matter of availability and cost must be considered.

Following drawing and trimming, the jackets are washed clean of lubricant and dried. They are then ready for assembly (See Fig. 32).

Assembly

Bullet assembly comprises the following steps:

Soft- and Hollow-Point	Full-Jacket
Feed jacket, base down	Feed jacket, point down
Feed core	Feed core
First point	Seat core
Second point	First closure
Knurl	Cone (for boattail)
Final size	Final closure

For pistol bullets with open hollow soft points the hollow is made on the pointing operation. On hollow-point rifle bullets, the first point operation is replaced by a core seating punch, followed by the pointing.

The trimmed jacket length for hollow-point and open-point match bullets is such that the core does not completely fill the assembled bullet. The length for soft-point bullets is adjusted for the proper amount of lead exposure in the finished bullet. For full-jacket bullets, enough jacket length beyond the core is left for final turnover and closure.

Specialty bullets, such as Silvertip and protected point types, require extra assembly operations. The Silvertip jacket is added as a cup just prior to pointing. The pointing punch forms the tip jacket to its final shape. Plastic point protectors are usually added to bullets after final knurling and sizing. Metal type points are added during assembly.

At assembly, cores and jackets must be clean and dry. Moisture or oil between jacket and core prevent adherence between the two surfaces. Also, barrel friction, the heat of firing, and air friction during flight combine to heat any trapped moisture

to its boiling point, creating disruptive steam inside the bullet. Accuracy suffers.

It is permissible to apply a very, very light coat of oil to the outside of a jacket to ease wear on assembly tools. After assembly, tumbling in ground corn cobs (Maizo) cleans and polishes the bullets and removes any assembly lubricant.

Soft-point bullets must be tumbled in an excess of polishing media at a slow rate, so as not to mutilate the soft points.

Care must be taken, when polishing open-point bullets, to use a polishing medium of a larger granulation than the diameter of the point opening.

Quality controls on bullets at assembly include close control of bullet diameter, checks on weight, shape of ogive and heel, concentricity of ogive with heel, boattail and body, and location and depth of knurl.

If weight control is maintained on jackets and cores going to assembly, obviously there will be no problem of weight in the finished bullet. Diameter is checked often enough to detect bullet diameter approaching maximum as sizing dies wear. Bullet upset in water is checked with each lot of jackets. Shape is checked when changing pointing punches, using an optical comparator.

The bullet heel, as discussed under accuracy, must be carefully controlled as to shape and concentricity.

Knurl location is controlled from the bullet point, in order that proper overall length at loading may be maintained while keeping the case mouth crimped in place on the knurl.

Some military bullets have a groove cut into the body of the bullet instead of the knurl. This is not commonly done on hunting bullets as the bullet is more liable to break in two on impact at the cut section. Either method works as far as keeping the bullet in place before firing is concerned.

When one views the various open-point and soft-point pistol and revolver bullets, it is apparent that their assembly is much like that of soft-point rifle bullets, except that the jacket is relatively shorter and lead exposure greater. The final point shape, including any hollow, is formed in the final assembly die. Jacket material is generally thinner than with rifle bullets. The 95/5 alloy is favored.

Lead Shot

Along with bullet making comes the manufacture of lead shot. Methods of making shot by dropping molten lead in a shot tower have been well covered in American Rifleman (January, 1973), as well as other places, and will only be reviewed here. The newer "Bliemeister" process will be covered in more detail.

Shot, as most shotgun shooters know, is made in varying degrees of hardness. Lead, with a very small percentage of antimony added and also a small percentage of arsenic, makes the softest shot called drop shot. Harder "chilled" shot may contain up to 5 or 6% antimony, also with a small amount of arsenic. Shot can be made still harder by copper or nickel plating, and such shot is used where the very tightest patterns are wanted, for handicap trap shooting, and for long range pass shooting. The plastic shot cup does about as good a job of protecting shot from deformation as does plating, however plating does help some.

Arsenic in the alloy has the effect of making the shot assume a spherical shape quickly during the drop, so that the shot when cooled is perfectly round. Only a small percentage, about 1/10%, is necessary.

The old shot tower is still a good method for making shot, but is expensive to build and operate. Height from start of drop to landing in water needs to be as much as 150 ft, depending on air temperature and shot size. Larger sized shot can be made in the cold winter months, BB's and 2's for instance, if the tower is not high enough for the full season.

The process is relatively simple. Molten lead from the melting pot flows at a controlled rate into a pan with holes in the bottom. The pan at Western was an actual cast iron skillet drilled with a myriad of holes in the bottom. Hole size varied with the range of the shot sizes being made. The inside of the pan was covered with a layer of inert non-melting fibrous material, which spread the molten lead evenly over the bottom of the pan. A rapper banged the pan with a steady beat, causing the lead to fall in droplets. During the long fall down the tower the shot shaped up into spheres through surface tension, and cooled enough to resist deforming when they hit the water at the bottom.

The newer Bliemeister process does away with the old-fashioned shot tower. Instead of falling a long distance through the air, the shot fall less than an inch before landing in hot water. The Bliemeister patent drawings show a trough-like tank, 4 ft, or so, long and perhaps 4" wide, having a row of holes along the bottom. Below these holes is another plate spaced slightly apart, with holes corresponding to those in the trough. Below the first plate, again spaced apart, is a second plate also with holes corresponding with those above. The lead flows through the series of holes which serve to slow its passage and meter it, so that it flows at a slow, steady rate from the bottom hole. The trough is equipped with a rapper, so that the shot break off into droplets. The trough is located just above a tank of water, heated to near boiling. In the tank, a 6"-wide pine board along the trough is suspended, tilted, so that shot droplets roll across its width and continue through another 3 ft., or so, of hot water to the bottom of the tank.

Hole sizes regulate the size of the droplets. Water temperature controls the cooling rate, so that shot

are allowed to become spherical through their own surface tension.

The trough is fed from a large lead pot. An overflow in the trough serves a double purpose; a constant melted lead level keeps the droplets forming uniformly, and dross or slag floats out so that there is only clean lead in the trough.

Shot, formed by either the Bliemeister method or in a shot tower, receives the same finishing treatment.

The wet shot are first passed through a gas-fired continuous drier. From the drier, they roll on to a series of sloping triangular tables cascaded so that the shot rolls down from one table to the next, jumping a gap between tables. Imperfect, odd shaped, or clustered shot fall in the gaps and go back to the melting pot.

Those shot which make it over all the tables and all the way to the bottom are to be congratulated on their near perfect rotundity.

The next step is polishing with graphite in a tumbling barrel. From polishing, the shot flow into an inclined rotating drum screen for sorting to size. The screen has the smallest holes at the start and graduates to the largest holes at the lower end. Shot sizes from No. 9 to No. 4 are segregated by the screens and go to separate bins for bagging or for loading.

There are other ways of producing small shot sizes, but none is as efficient as the two methods described.

One other method, suited only for small quantities of shot, utilizes extruded lead wire. The wire is drawn to the required diameter. It is then fed to a cutter looking something like two combs, one shearing down through the other. A feeder pokes a length of wire across the length of the stationary cutter comb. The shearing cutter teeth pass through the teeth of the stationary cutter, cutting the length of wire into little cylinders. The size of the cylinder and of the ultimate shot is determined by the diameter of the wire and the spacing of the cutter teeth.

The cut cylinders, their diameters equal to their heights, are tumbled with graphite until they have beaten themselves round. This is a slow way of making a not very high quality shot, but it does not require a large investment for tower or machinery.

Obviously, the higher the antimony content, and the harder the cut slug, the longer will be the tumbling to make the shot round. No screening of shot size is necessary in this process.

U.S. Patent No. 4,108,297, dated August 22, 1978, describes a still newer, simpler way of making lead shot. The inventors are three men, probably related, all named Francis, one being from Australia, the others from England.

According to the patent, molten lead is poured into a heated V shaped trough called the "shot pot" with holes along the base of the V.

Droplets falling from the "V" pass through a gas torch flame, which helps them to form into spheres. After a fall of about 2", the shot land in a quench bath of cold water, the cooler the better. Drying, polishing, and screening follow.

Because of the short fall, the shot hit the water at low velocity and are not deformed. At the same time, the shot are not all perfectly spherical, again because of their short fall through air.

Shot, mostly in the larger sizes, may be made from wire by the cold heading process. The header cuts a slug from the wire and squeezes it between two punches in a die. The punches have hemispherical hollows in their ends which form the slug into a nearly round pellet. The pellet is rounded out by tumbling. This process works best with buckshot.

Western, at one time, made buckshot using a continuous casting machine. Two wheels between 2 and 3 feet in diameter, with flexible rims were mounted close together on a horizontal shaft which could be rotated slowly. Rollers against the wheel rims at their uppermost point pressed the rims close together. At their lowest point, the rims were forced apart by a divider. On the inner opposing surface of each wheel a hemispherical cavity was milled opposing a similar cavity on the opposite wheel. A small funnel opening at the top of each cavity allowed molten lead to flow into the spherical cavity formed by the two wheels when pressed together as they passed the pouring spout at the top. The shot cooled as the wheel turned, and fell out as the wheels separated at the bottom. The small sprue left from the casting was blended into the shot by tumbling with a small amount of graphite.

Steel shot, now required by U.S. Federal law in some areas of the United States, must be softer than the barrel in which it is used or, the barrel must be protected by a shot cup of the plastic type. Even the softest steel shot, if rusty, will scratch an unprotected barrel.

The first experimental shot were made from very pure iron, the softest metal in the iron and steel family. When free of rust, these shot did very little damage to gun barrels. Cost, however, ruled out the pure iron in the long run.

Quite a few shooters in the past, and I suppose they are still doing it, have loaded steel ball bearings in shells in place of buck shot, or sometimes steel air rifle shot when a smaller size was wanted. The result is not wholesome as far as the barrel is concerned.

The very hard steel shot, pressing against the relatively soft steel barrel, leave perfectly straight lines down the barrel from breech to muzzle, and tend to expand the choke as well. Nothing creases

a barrel like a hard steel ball.

More than one such customer has complained about damage to his gun from the company's shells, and has sent in his gun barrel to prove it. The evidence was always plainly against him. When steel bearings are fired, they leave their own indelible print.

The manufacturer of steel shot requires special equipment of the type used by ball bearing makers. For years, Winchester made steel air rifle shot by the similar process of cold heading pellets from wire, then grinding the pellets to size and roundness in ball grinders of the rotating plate type, where final size was dictated by the spacing between the plates. The process was too slow for small shot, but produced fair quantities of larger shot.

Before the days of steel shot, an attempt was made to make lead shot which disintegrated in water, rendering them safe to use in wild fowl areas where dabbling ducks feed.

Magnesium was alloyed with lead. Magnesium is a very active metal, reacting strongly with water when not protected by a coat of oxide on its surface.

This project looked promising, but it turned out that the magnesium was a little too active. Under storage, aggravated by high humidity, disintegration started, creating enough heat in the process, to pose a potential fire hazard. Back to the drawing board.

Iron Bullets

For a time, when shooting galleries were still an attraction at the amusement park, but along towards the twilight end of the game, iron bullets were used in some .22 Short gallery cartridges. These bullets were not solid iron, but were of iron powder mixed with a plastic powder and formed under pressure.

Iron bullets had advantages over lead bullets. The iron powder cost per bullet was less than lead. The compressed powder broke up into fine harmless dust without ricochets on striking the back stop. They also made a nice flash of light as they struck. The energy of impact heated up the iron particles so that some sparked briefly.

True, the bullet was light, and at longer ranges would lose velocity too rapidly to be very effective, but at the short range of the average gallery, they worked nicely.

A "Stokes" rotary press, the same kind as used in making small tablets and pills, was used. A rotating turret had a series of punches around its circumference, which were moved up and down, in and out of a central wheel-like plate with holes of the proper diameter in it. A scraper, working on the surface of the rotating plate, filled each hole with powder in turn. Top and bottom punches moved in to squeeze the powder into bullet shape. The top punch rose to clear and the bottom punch rose enough to push the bullet to the surface of the plate, where a second scraper moved the bullet off into a work pan.

The pressed bullets then went to an oven where they were baked to harden the plastic.

The bullets were then lightly waxed, and were ready for loading. These relatively soft bullets were no harder on barrels than are lead bullets.

CHAPTER IV
SHOTSHELLS

In 1935, when my education in shotshell manufacture began, the biggest thing that had happened in the way of new developments in many years was the introduction of the high velocity Super-X shotshell, pioneered by John Olin, in the 1920 s.

In the beginning, Western had to import a special powder from Europe for these loads. In a year or two, American powder makers caught up.

The folded crimp, plastic case, and plastic wads and shot cups were still unknown. Paper tubes, top wad and rolled crimp were the order of the day. Still, ammunition makers were aware that there was room for improvement in shotshell performance and were doing something about it, spurred by competition, which was always keen.

Western was ballyhooing its short shot string, having found a means to measure it in flight, and was busy on ways and means to deliver the maximum amount of shot in the shortest possible interval of time—the short shot string concept. Work was also going on to get rid of "blown" patterns, balled shot, and leading. All the other ammunition companies were presumably doing likewise.

The Grand American Trap Shoot at Vandalia, Ohio, when I first started going, had long been a battlefield. Shooters, together with bands of company missionaries bringing the word on various shooter products, gathered yearly for head to head competition, shooter against shooter, missionary against missionary. The shooters vied for fame and money prizes. The ammunition makers' missionaries vied for the biggest share of the shell count and for converts to their brands. Along with the ammunition makers, the powder makers were there also, as the shooter in those days not only had a choice of ammunition brand but powder brand as well. The various gun makers were on hand, but not as much in evidence as the ammunition people.

There was always a watchful eye at the shell counter, making sure that nobody switched a shooter with a last minute nudge.

Any competitive advantage any company could see was rushed into exploitation by the colorfully uniformed, highly identifiable ammunition men. Let one side falter the least in performance, the other gleefully spread the word.

Ammunition for the Grand had been made well ahead of time, carefully tended and nourished, double and triple tested and inspected, and well sprinkled with blessings. Even so, with more than a million rounds of each popular brand fired and each round recorded as "dead" or "lost," the factory was always a bit on edge until the final scores were in.

Such a competitive spirit did much to bring on shotshell improvements. The Grand provided a well documented and closely observed broad field test and a final OK on a development already well checked before entrusting it to the merciless line of shooters.

Shooters needing an alibi for a lost target were wont to blame it on a hard target—one difficult to shatter—or on a hole in the shot pattern—a blown pattern. Sometimes the shooter was right about the blown patterns.

On alternate years, Remington and Winchester-Western furnished the traps and targets. Somehow each year the rumor got out, source unknown, that the targets were "hard," compared to the preceding year's. Soon a counter rumor came around that the competitor's shells were heavier on recoil, more kick. Friendly competitive propaganda. Nothing proven either way, but each year about the same percentages of birds were broken.

Blown patterns were attributed to all makes of ammunition somewhat impartially. Two main causes were considered responsible. One was interference by the top wad, which had to be pushed out of the way by the on-rushing shot charge. The other was "balled shot," clusters of shot welded together by hot gas leaking past the wadding. Both causes did tend to leave gaps in the pattern, through which the relatively small target could slip. Gas leakage also caused leading of the gun bore. When leading builds up to where it deforms pellets rubbing against it, some additional pattern dispersion can be expected.

Leading, being a visible thing easily seen by the shooter, was a prime target for improvement.

A peculiar thing happened when gas leakage was reduced with better wadding. Careful, extended pattern testing in the factory showed that the incidence of blown patterns increased, even though balled shot and leading were done away with. It seems that gas leakage had been a mixed blessing. Moving faster that the shot, the gas had been blowing the top wad out of the way ahead of the shot. Less gas leakage made getting rid of the top wad a must. Remington came up with its

8 segment, folded crimp, followed soon by W-W with its 6-segment crimp, take your pick. Federal countered with a frangible top wad, which broke up into small, non-interfering, pieces.

The folded crimp opens a little easier than the rolled crimp, and powder speeds had to be increased to adapt the standard loads to the new crimp, in order to avoid potential squibs and low reports.

Some new developments, introduced at the Grand, didn't pass with flying colors. One new wad combination, brought out with much fanfare, quickly fell by the wayside. The light part of the wad collapsed too easily, dropping pressure, slowing burning, and creating an occasional "rain barrel"-sounding boom, which, like the Revolutionary "shot heard around the world," reverberated with even more fanfare at the Grand. On top of that, the wadding combination was considerably heavier than the competitor's wad, adding about 5% to comparative total recoil. That's not much added recoil for one shot, but over several hundred targets, it could add up to greater shooter fatigue. That news was duly broadcast. The shell count swung the other competitors' ways that year.

Wadding was given much attention in the late '20s and the 1930s. Gas leakage with its attendant leading and shot balling were an enemy worthy of attack. Besides, felt wadding was getting more expensive. Felt did a good job of filling space in the case, but didn't do much in creating a good gas seal.

Western went part way by introducing a double ended wad with a shallow cup at either end. The wad was made by mixing finely ground cork and cork dust with partially polymerized tung oil, pressing to shape, and baking to harden the oil. The cork wad was resilient and did improve the gas seal, but was expensive to make.

One of my several research projects in the mid-thirties was that of checking out possible substitutes for the ground cork. One of the substitutes was wood fibre, directly replacing expensive cork in the wad.

This work had an interesting sidelight. Pete Brown, while working on the development of a load which would deliberately spread the shot charge for short range quail, rail and woodcock shooting, made up some cork wads, which were roughly bullet shaped. Loaded cup end down, Pete figured that the conical end, thrusting into the shot charge, would spread it. For some reason, this it didn't do. Patterns weren't much affected, but what did happen was that the wad closely followed the path of the shot, and punched a hole well toward the middle of the pattern. So maybe here was a way to make a tracer-like load, using the wad to indicate the shot path. Great for beginning shooters.

More experimental wads were made up with Pete's special shape, but using wood fiber with the tung oil, killing two birds as it were—my wood fiber experiments and his tracer wad.

Somebody had to do the shooting, and Pete and I were elected. There's a big difference in shooting a shotgun at a moving target and at a passive piece of paper. After several hundred patterns, shooting becomes a little less than fun, particulary with Super-X loads. Recoil seems to get heavier every shot. The old flinch finally creeps in. Counting shot holes can also get a little tiresome after two or three hundred patterns.

After all the data were in, it was concluded that, while the wad did routinely center well in such patterns, it lagged too far behind the shot charge to give an accurate estimate of lead. Besides, the wad was too difficult to fit with an illuminating tracer. Tracer project abandoned, wad project fairly successful.

Pete and I cultivated a healthy dislike for the partially polymerized tung oil, used as the binder. It proved the most cohesive, adhesive, sticky, ornery gunk we'd ever tried to let go of but couldn't.

Not much got done on shotshell development during the war years, but in the years immediately following much was accomplished.

Again attacking the gas leakage and wad cost problems, Western came up with a big advance—the cup wad, a bottle-cap shaped wad made right on the loading machine from a disc of heavily waxed, Kraft paper. This was loaded cup end down and topped with a light, lubricated, molded wood-fiber wad.

The bottle-cap shaped corrugation around the skirt of the cup wad was to let the trapped air past the wad as it was seated against the powder. Under the sudden thrust of primer and powder gas, the wad sealed perfectly, and gas leakage was effectively stopped.

The molded fiber wad was made on a special machine developed by Keyes Paper Company, utilizing a slurry of pulped fiber in water. Somewhat reminiscent of a certain machine invented by a man from Racine, the machine did a lot of things to the pulp before depositing a bevy of little round ejecta on its far side. A trip through the drying oven, then over to an edge lubricator, and the result was a light resilient wad to back up the cup and to fill up excess space in the shotshell case, as all wadding must.

The cup wad was so versatile and efficient that a 16-ga. shell would give reasonable performance in a 12-ga. barrel, and a 20-ga. shell would likewise do a fair job in a 16-ga. barrel.

Editor's Note: Readers mindful of the consequences of a "12-ga./20-ga. Burst" [to be discussed in Chapter X], need to remember that a 16-ga. shell, outside diam.-0.731", will not drop *into the barrel* of a 12-ga. gun, nominally 0.729",

inside diameter, as will a 20-ga. shell, with head/rim diameters of 0.697" and 0.766" respectively.

On one occasion, some of the factory group went on a duck hunt up the Illinois River, and on arrival just at daybreak found that they had brought 16-ga. shells instead of 12s.

Desperate, they scrounged around on the sand bar and found several fired 12-ga. shells from somebody's previous hunt. Cutting the paper tube off the 12-ga. and splitting it, they wrapped the paper around 16-ga. shells, which were then loaded one at a time in their 12-ga. chambers. They came home, embarrassed, but with a limit of ducks.

The cup type wad worked so well that the Western engineers started work on a machine to utilize the same wad in the base of the shell to get rid of another long-time bugaboo—swelled heads (shotshell heads, not engineers'). By punching a hole in the middle of the cup, it was possible to rivet the wad in place over the wound paper normal base wad, using the base wad paper itself. This combination of opposing cups ended up as the "sealed gas chamber" in the company's advertising, and did perform exactly as advertised.

It had been the custom for years to reinforce the shotshell head on heavy loads with an inner steel cup. The paper base wad, wound spirally, then mashed in place in the head of the shell, did allow a certain amount of high pressure powder gas to pass between the layers of paper and swell the brass head. Hence, the steel reinforce.

The cup wad cured that trouble, but another small trouble appeared, mostly at trap and skeet fields.

A small amount of gas was sometimes able to sneak under the cup wad through the hole in the center and became trapped. As the pressure in the shell dropped, this trapped gas expanded and occasionally loosened the base cup wad. Finding the wad loose in the shell or in the bore, the shooter would naturally become alarmed, but needlessly so, as the light wad would not have damaged his barrel.

The assembly process was modified to eliminate the problem, but it was rumored about that for some time after, one or two zealous rival salesmen found it hilarious to cut a base cup wad from a fired shell, drop it quietly in a strategic place on the trap field, and then dramatically discover it later. I've forgotten what the counter ploy to this was, but salesmen are an inventive bunch.

There was another perennial problem with paper shells. Tubes shrank in dry weather and swelled in wet.

The maker had to guess what shells made in the dry heat of the summer would swell to in the rainy fall season. American shells were usually treated with paraffin to make them more water resistant, while many European shells were lacquered.

Paraffin, also, surprisingly enough, served to prevent the hot powder gasses from burning holes through the paper tube.

World War II brought along two new developments, which were adapted to paper shotshells. Shotshell tube paper, a multilayered paper, had its outer layer treated with a new plastic material, melamine, which increased the wet strength of the paper, making the tube less soggy when damp.

New waxes for moisture-proofing military packaging, called microcrystalline waxes, had been developed. The crystalline structure of the solid wax was of a type smaller and more dense than that of ordinary paraffin, presenting a more difficult barrier for water to penetrate.

When these two improvements had been made in paper shotshells, much of the swelling and shrinking problem went away.

In the 1950s, Western had found that a plastic strip around the shot charge inside the shell, placed there to protect the shot charge in its travel down the bore, eliminated leading entirely, and, because fewer pellets were damaged in firing, patterns were greatly improved. This was the last development before the plastic wad and shot cup came into being.

Some years after leaving Winchester-Western, I appeared as an expert witness in a murder trial where this plastic strip played a curious role.

One night in 1963, I had a phone call from an attorney in Butte, Montana. He had need of an expert witness, and in desperation had called Ithaca, the maker of his client's shotgun. A friend there had referred him to me.

The case involved a man who had shot his wife, accidentally he said, during a quarrel. She had loaded a shotgun and had pointed it at him; he had taken it away from her unfired. He was sitting on the edge of the bed, gun across his lap, talking, when she grabbed the barrel to pull it away from him. His finger was on the trigger, and the pull fired the shotgun. The charge struck her in the chest and killed her on the spot.

Only the shooter and the victim were present; but neighbors were next door with ears to wall.

The neighbors' story was that they heard the loud quarrel, heard somebody enter the closet and move something, later heard her say, "You'll be sorry," and still later heard the shot. The neighbors called the police. The charge was murder.

State-appointed defense counsel wanted testimony as to distance between gun muzzle and wound. If close enough, defendant's story had some weight. If too far, the victim would not have been able to reach the gun and pull on it. The shotgun was available, but no ammunition.

Before the trial, I had a chance to examine the woman's shirt. Alongside the entrance hole, there was a peculiar small rectangular gray smudge,

obviously associated with the damage to the shirt.

The Super-X shell with the plastic strip shot protector was then quite new on the market, but I was sure that one of the plastic strips had caused the mark, and the prisoner agreed that he had had a Super-X shell, but didn't know anything about its insides.

We located a box of Super-X at his store, checked and found the plastic strip type of loading and only one size of shot was available.

So we had a good start on duplicating the essential conditions, as the hole in the shirt was well defined enough to draw conclusions without a back-up victim inside the shirt.

Using cloth of the same weight and weave as the shirt material, and firing at various distances to determine the relative shot spread, the actual strip mark was duplicated more than once.

As estimate of distance could then be made using the same gun, same type of ammunition, and similar piece of cloth.

The distance looked to be at least 4½ ft. from muzzle to cloth but less than 6½ ft., indicating at the very least the victim had unusually long arms.

That night the attorney and I visited the prisoner and told him my findings. Did he want me to testify or not? He stuck by his story, and asked me to testify, as he felt the distance was near enough.

In court, after being duly qualified as an expert witness, and having introduced exhibits from the tests, I was handed the shirt and asked my opinion as to distance. The jury did not know that I had already seen the shirt, but feeling that a certain amount of deliberation on my part might add more weight to the testimony, I asked for a little time for the examination. Comparing shirt and cloth exhibits with a magnifying glass, and considering the overall evidence for a brief moment, I climbed back into the witness chair and gravely nodded to the defense attorney.

"Now that you have examined the evidence, what is your opinion?"

"In my opinion, the distance was at least 4½ ft. but not more than 6½ ft."

On cross examination, the prosecuting attorney, who knew I had seen the shirt before the trial, said in opening, "We appreciated your little act. Now can you place the distance more accurately?"

The answer being, "No," I was allowed to leave the stand, but told to stand by.

At recess, the judge and the two attorneys were talking hunting, when I asked to be excused if possible as I had an important engagement in Idaho the next day. The answer was yes, as all three had hunting engagements the trial was keeping them from, and they all wanted a several day postponement. Amid such candor, I could only confess that my appointment was with an elk.

In Montana, as in Idaho, there are priorities, and the wheels of justice may grind a little more slowly during the hunting season. No one foolish enough to land in jail during the fall months should expect anything different.

The jury believed the man, I found out later, and he was acquitted.

Back to shotshells. By the time all the changes mentioned had been made in paper shotshells, they stood at the highest stage of development ever, and no better shells had been made up to that time.

On the horizon, however, were growing tinges of plastic.

Western was working, off and on, with plastic shells as early as 1936, experimenting with cellulose acetate. The shells lacked strength, cracking at low temperatures and being too soft at warmer temperatures.

The development of the Reifenhauser plastic tube, with its oriented molecular structure, made possible a plastic-tubed shell of adequate high- and low-temperature strength. The addition of a paper or plastic base wad took care of head swelling. Cost was still a factor. The shell had to be assembled from three parts, not counting the primer. In addition, reloading was growing increasingly important, and the three-piece shell, though reusable more times than a paper shell, didn't quite satisfy the ardent reloader.

The next logical development was the compression molded solid plastic shell, typified by the AA plastic shell marketed by Winchester. The brass head, or more commonly now, a brass plated steel head, is still used for two or three main reasons—positive extraction, primer sensitivity, and traditional appearance.

If an automatic shotgun is even slightly out of time, so that the action starts to open before the pressure in the chamber has dropped, the extractor is apt to pull through a plastic rim, leaving the shell in the chamber. On earlier paper shells, the head was sometimes pulled right off.

The metal head crimped on over the plastic base makes the head stronger and more rigid, giving better support to the primer, and consequently better sensitivity. And it doesn't pull off nor does the extractor pull through the rim.

Shooters are very conservative and traditional as regards drastic changes in appearance in hunting and shooting gear. Metal heads on shotshells do dress up the appearance, and have been with us for as many years as we've had shotshells. A high brass head has long been a symbol of greater power inside, even though height isn't needed.

In the time of the paper tube, it was found that top of the base wad inside and top of the brass head outside had to be at different levels. The tube would frequently cut off when fired if the two heights coincided. For heavier loads, more space

was needed inside for powder, so the base wad was lowered and the brass height had then to be raised. Conversely, with light loads, base wad height was increased and the brass height lowered. No cut-offs. Tradition is maintained with plastic shells. High brass for high velocity. Low brass for light loads.

The latest thing in shotshell developments is a shell called the ACTIV, sold by ACTIV Industries of Kearneysville, W. Va.

The shell is a step beyond the conventional shell made from a Reifenhouser tube and headed with a plastic base wad and brass or steel head. The ACTIV shell has a plain steel insert molded in place in a plastic head itself molded onto a Reinfenhouser tube. The head joint appears integral with the tube.

Cost would appear to be an advantage with this type of construction. The steel insert is easily stamped from sheet shell, needs no plating for rust protection, and so strengthens the head that no outer brass or steel head is needed.

Extended tests by H.P. White, a well known independent testing laboratory, show excellent functioning characteristics including hot and cold tests, high pressure tests, and tests with a variety of powders. Reloadability is good, and the shell shows wide adaptability in the matter of possible loadings.

With greater interior volume, magnum loads in a 2¾″ case are possible.

Because the steel reinforce extends into the rim of the shell, the bugaboo of the extractor pulling through the rim is avoided. As with all plastic shells, the folded crimp is used.

Today's shot charge gets pretty well coddled when fired. No hot gas to melt its surface, a tough sleeve or cup of plastic to prevent shot from touching the bore, and a certain springiness to the wad, to take up the shock of igniting primer and burning powder—well characterized by Federal's catchy name, "Pushin Cushion." The latest development is a space-filling soft granulated filler for the shot to nestle in on their short trip through the barrel with its constricting pucker at the end.

The variety of wads made of plastic now in use attests to man's imagination. All the cups protect the shot, all the cup-like shirts at the powder end of the wad effectively seal the gas, and the middle section of the wad does some sort of a job of taming the starting shock.

A brief look at any one of the several reloading guides shows that, under a given set of conditions as regards powder charge, primer, and shot weight, there are significant differences in pressures, givening the same nominal velocities, with different wads.

Ultimate choice of wad type again is a function of powder consumption and unit cost, pattern performance, and ease of loading. If one is inclined to produce wads in-house, there is complexity of mold and ease of manufacturing, not to mention weight of wad. Plastic for molding is a heavy item of expense, although cheaper per pound than smokeless powder.

Granted that standard velocity is achieved with a given wad, the remaining principal criterion of its performance in a shell is pattern percentage.

In order to establish a wad design, or a choice of one of the existing wad designs for optimum pattern performance, testing would need to run to a hundred or even several hundred or more patterns under carefully controlled conditions to arrive at anything like a significant answer. One lot of powder, one lot of shot, individually counted shot charges, one lot of shells, randomized loading, randomized shooting in several guns, would give an answer to one load at least, but not necessarily to all possible loads. It's great fun for the enthusiastic ballistician, but a little expensive. The ultimate wad probably hasn't been hit upon, but there isn't too much room for improvement any more.

Today's plastic shotshells are of two general types—an all plastic one-piece molded shell with or without an added brass head, and a composite shell made using a plastic tube, a separate base wad of either plastic or paper, and the usual brass or steel head.

Winchester-Western's AA plastic shell is typical of the former, and there are many brands of the latter.

Both types with few exceptions use the folded crimp, and, because the folds are bulky, the mouth of the shell is customarily made thinner than the rest of the tube. In the case of the molded shell, the thinning is accomplished in the molding.

In the composite shell, the inside of the mouth of the shell is often reamed to a taper, a separate operation known as skiving.

Molded shells are made by two means, injection molding, or by compression molding starting from a molded button. AA shells are of this latter type. The button, made by injection molding, produces a metered amount of plastic in a form easy to feed to the die and punch in the extrusion press to form the final shell.

The die is essentially a hole, the closed end of which corresponds to the head of the shotshell. Into this cavity a molded button is placed. As the molding punch enters the cavity, the plastic is forced under the pressure of the punch into the shape of the rim and primer pocket. At the same time, plastic is extruding back along the body of the punch to form the tube. The shell, of course, now having a rim, has to be removed from the closed end of the die after the punch is withdrawn.

The other type shotshell tube is made by the Reifenhauser process, which gives the plastic from which it is made special treatment to orient the

plastic molecules for greater strength.

Essentially, the process starts with extruding a plastic tube, which is then simultaneously stretched in length by drawing it out and stretched in diameter by air pressure applied inside.

The tube is made continuously and is next cut into standard 2¾" or 3" lengths or others as required for different shotshells.

The brass head is commonly made by the conventional blank and cup process. Sometimes it is made on complicated progressive dies which successively start the formation of the cup from strip, draw it to final length, pierce the head for the primer, emboss it with the usual head identification, and remove it from the strip by pinch trimming it in the final die. This treatment is followed by rolling on the ring or knurl.

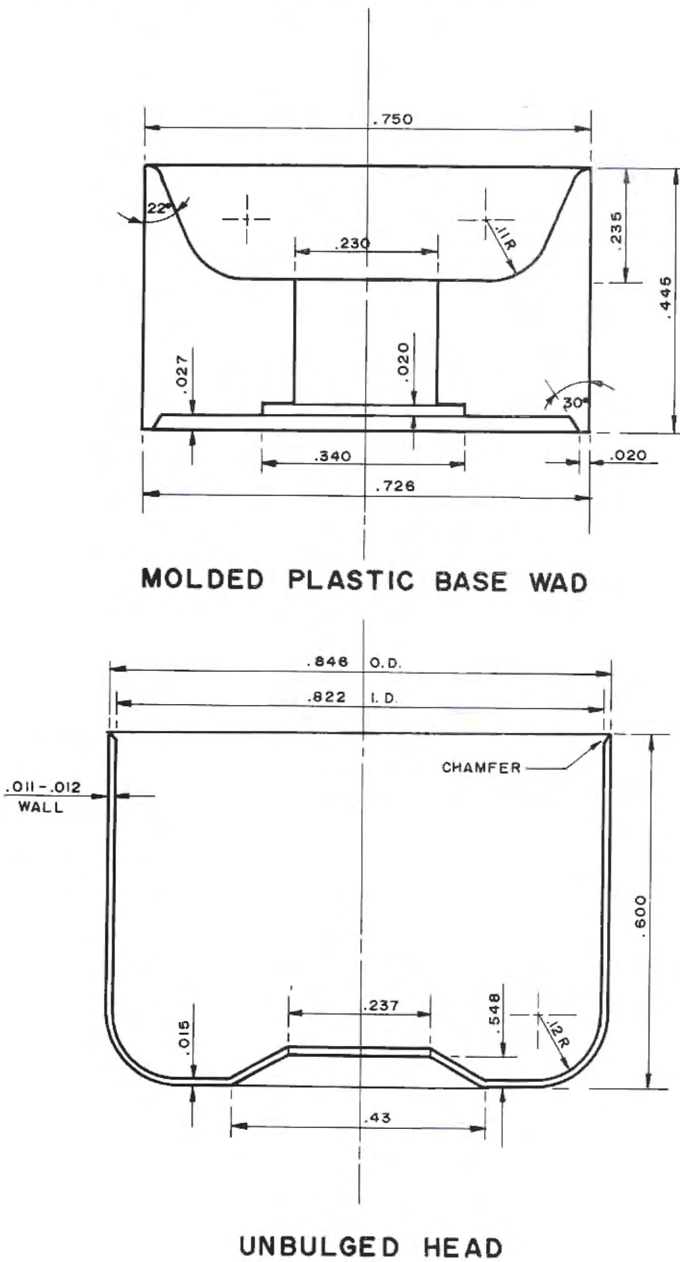


Figure 33: Composite Shotshell Head and Base Wad

Then, depending on final assembly method, the rim may be partially formed by a press with an expanding punch. The cup may be either brass or plated steel.

For the molded shell with rim, the head cup has an interior diameter slightly greater than the plastic rim diameter. This type of head may also be used with the composite shell (See Fig. 33).

After the head is slipped over the plastic tube, a die reduces the diameter of the cup to fit the outside of the tube, and at the same time by downward pressure forms the final shape and diameter of the head.

For the composite shell, using either type head cup, the base wad—either a coil of paper or molded plastic—is placed in the tube. An inner punch shapes the paper base wad, compressing it in place around the primer hole pin, while an outside die further flattens out the rim to its final form and diameter.

It is common practice, when the base wad is of paper, to insert the primer in the head before finally compressing the paper into shape.

Chief disadvantage of paper for base wad is its propensity for shrinking in dry, hot climates. Shrinkage loosens the coils of paper enough for hot powder gas to pass through, swelling the head, and even, under some extremes, causing bursting of the rim. It was for this reason that an inner steel reinforcing cup was for years used on high velocity, high brass loads. It is not necessary with plastic base wads, unless the head thickness is pared thin to save expensive plastic.

Note the shape of the formed plastic base wad. The small raised ring on the bottom edge of the wad is crimped into the inner cavity in the metallic rim, locking wad, tube and head together.

One important thing to remember about the brass or steel head is that the lip of the cup must not be trimmed dead sharp. The inside must be chamfered slightly. Otherwise, under the pressure of firing, the tube may shear on the sharp corner and separate from the head.

It is good practice to maintain the top of the base wad and the head at different levels to minimize a stress concentration in any one area of the tube, as discussed earlier.

Many plastic materials have been tried on shotshells, either as tubes or as entire molded shells. With new materials or combinations of materials coming along constantly, the day may yet come when a plastic shell, entirely satisfactory in all performance respects, can be made by single injection molding techniques. In fact, some claim success already. The shooting public will quickly prove or disprove the claims.

One of the principal problems a shell has to overcome is that of the wide temperature range over which it is expected to perform. Winter hunt-

ing temperatures are frequently sub-zero, while summer temperatures especially those for storage, or in the trunk of a car, may exceed 100°F.

Plastic response to this wide range of temperatures may well run from glass brittleness to putty soft. The ideal shotshell plastic should retain flexibility at −40°, and strength at 130°F, if the resultant shell is to be used throughout the North American continent, for instance.

A shell used only the tropics need only face the high end of the temperature range, and a suitable plastic is not quite so difficult to compound.

Not the least of the considerations in plastic shotshell making is material cost. Some physically suitable plastics may simply be too expensive for shotshell use. The plastic portion of a compression molded skeet or trap shell weighs about 76 or 77 grs., so that a pound of plastic will produce 90 or 91 shells. ABS plastic currently sells for some $3.50 per pound. The 11.1 pounds of plastic in 1,000 shells then would cost $38.85.

The plastic base wad, if produced separately, would weight 24 grs., more or less, depending on design. A paper wad weights about the same. With base wad plastic at $2.30 per pound and paper at $0.70, the economics would seem to favor paper.

Both types of base wad need a machine to produce them, an injection molder for the plastic wad, and a wad winder for the paper wad.

The wad winder takes a strip of paper which it has cut to the right length, winds it into a coil, and inserts it in the shotshell tube, ready to be headed.

There are two ways to produce the head from a cup (See Fig. 34). Commonly, the cup is drawn to a diameter near its final need. A section at the rim is then bulged outward by an expanding punch. At assembly the bulge is flattened out to form the rim. In so doing, tube and base wad are forced into the rim and pinched to lock the head on the tube. This style of head won't work with molded plastic shells with rim already formed. The inside diameter of the head must be large enough to accept the rim.

Figure 34: Shotshell Head Construction

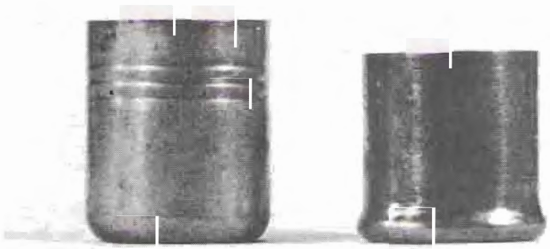


Figure 35: Shotshell Heads

Heading requires that a die reduce the head diameter to fit the tube above the rim. The outside rim is then formed around the plastic rim (See Figures 35 & 36).

The steps in drawing the head include:

1. Blank and cup from strip
2. Trim
3. Emboss head stamp, swell head
4. Pierce primer hole
5. Knurl
6. Wash and dry

Blanking and cupping follow conventional processes. Metal thickness runs .018" or less, as thin as .012" with some shells.

Trimming is commonly done by pinching the brass at the mouth of the cup between the punch and the die. Pinching leaves the mouth a little more ragged than a lathe type trim. The advantage is in eliminating a separate trim operation.

Empty Shell Inspection

Before loading, shotshells are checked for primer sensitivity, rim diameter and thickness, and head diameter under the rim. The force required to pull the head from the tube is also measured. Shells are also inspected for visual defects.

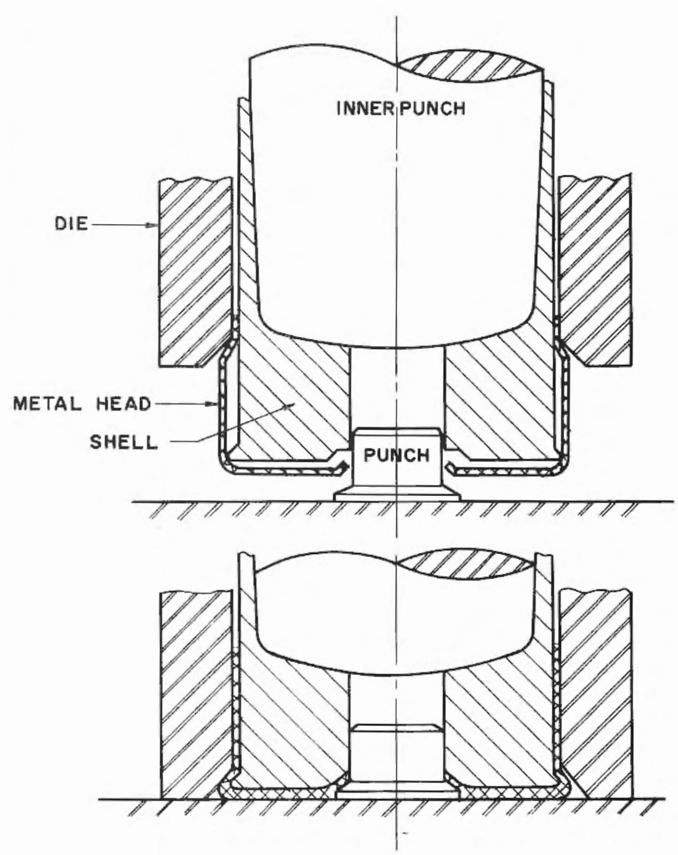


Figure 36: Head Covering a Molded Shotshell

CHAPTER V
CLAY TARGETS

The manufacture of clay targets is a natural follow-on to the shotshell business and so we will discuss it briefly at this point.

A great many shotshell rounds are fired every year at clay targets and it takes a surprising number of clay targets to supply the market. The Western Cartridge operation used to produce up to 125,000 a day and the department ran all day every day the year around. Like Remington, the company also made the traps for throwing the targets. The target and trap business is something like razors and razor blades. The trap is somewhat a one-shot deal for sales, whereas it takes countless numbers of targets to keep the trap going. Targets and razor blades are where the profit is.

Targets are made of a mixture of 40 mesh powdered limestone, coal tar pitch and/or petroleum pitch. The ratio in the U.S. is approximately 53% limestone and 47% pitch. The pitch cannot be all petroleum, as the target would be somewhat rubbery, so the mixture may be as much as half and half coal tar and petroleum. Benzoni in Bergamo, Italy uses a mixture of 60% filler, 40% pitch.

The melting point of the pitch used is approximately 92°C.

The weight of the target and its dimensions are governed by standards of the American Trap Shooting Association in the U.S., or to standards elsewhere. Olympic targets need to be tougher to stand the greater strain in throwing at higher velocities. If one studies the contour and design of the target, he will see that the rim is heavy, purposefully so, as it acts like a fly wheel to maintain stability. The rounded upper portion of the target, called the dome, has ridges running around it. These ridges have a purpose. They are to prevent the shot from ricocheting, so that a shot striking is more apt to break the target. Shot striking a glancing blow very close to the edge of the dome in passing are apt to leave only a small mark and not break the target. In order to make the target still more breakable, radial grooves are placed inside the dome to weaken the section. The center part of the dome, the flat section bearing the cup manufacturer's name, is called the poker chip.

It used to be favorite trick among the trap boys on the practice field to knock an occasional poker chip out. When the target is thrown, it sinks very rapidly like a parachute with a hole in it and a shooter is apt to shoot over the target.

At Western, to throw a little doubt into an occasional shooter as to his ability to break a target, there were a couple of aluminum targets, suitably black and properly painted, in the trap house.

Even with a good hit, the aluminum target only bounces a bit.

The great exhibition shooter, Herb Parsons, who never was known to miss a target accidentally, was with us on one of our informal skeet shooting sessions.

The trap boy waited until Herb was on Station 4 and slipped him an aluminum. It skittered off course, but with no visible piece broken off, and was called lost. Herb said nothing, but, before going to Station 5, suddenly found a loose screw in his trusty Model 12, and went to his car to get a screwdriver. Coming up to Station 5, the trap boy with glee threw out another aluminum. The rifled slug Herb had slipped into his pocket at the car took the crossing target squarely amidships and it left on a flip-flop flight to distant fields after a full left turn. Herb only turned around and grinned.

Coming up to station 8, we had another lesson. Herb called for doubles, broke the high bird almost as soon as it left the trap house, turned and effortlessly broke the second bird well short of the middle stake.

The machines for making targets consist of a melter, which melts the pitch, and passes it into the mixer, where the limestone is added. The mixer is jacketed and heated, so that the material, once melted, can be kept in the molten state until it is molded into targets.

The target press can be rotary type, such as the one made by Benzoni in Bergamo, which has 21 stations around its circumference. As each station passes under the metering device, a measured quantity of melted pitch-limestone is dropped into the target shaped cavity. Passing on to the next station, a punch comes down and squeezes the target into shape. As the turntable continues to rotate, the upper punch rises. On further rotation of the table, the bottom punch lifts the target out of the modeling cavity and an arm sweeps the target off to a final cooling conveyor.

A similar machine at Western operated on a hexagonal horizontal indexing drum. Each face of the drum had four cavities in it. As a face stopped in an upper position, a charge of the mix was metered into each of the four cavities. A punch came down, formed the target, and lifted. The drum then rotated and the targets were deposited on a moving belt where they cooled. The targets,

four abreast, marched up the slowly moving belt until they reached the painter. Here they successively were deposited on small whirling turntables and passed under the paint brushes. The paint brushes dipped into a container of paint and then descended on the target, painting either the entire top of the target or a colored band or the entire dome. The still warm targets then dried briefly and passed on down to the packer. The stacks of targets were wrapped in newspaper and deposited in the target container.

The ordinary container held 135 targets. The reason for the 135 figure was to allow a possible percentage of breakage, so that at least 125 targets, the quantity used by a squad of five for one round of trap or skeet, would be available as a unit package.

Target breakage in shipment is always a problem. The same busy genii who causes parcels in the mail to be mashed, and travelers' luggage to pass under the crusher, causes target cartons, marked "Careful, Fragile as Eggs" to land upon the ground with force.

The paint used on the targets comes in several colors—white, yellow, orange and red are the most common. The variety of colors is such that a color can be chosen for the best contrast against whatever background there is at the trap or skeet field.

In winter with snow on the ground, the obvious choice is generally the unpainted, all black target. For night shooting on the skeet field, the target could be painted with florescent paint inside and out.

Paint must be quick drying, but basically waterproof. Unbroken recovered targets do get wet, as do targets yet unthrown, on occasion. Casein based paints have worked well, as will some of the more modern emulsion paints; flat, of course, no shine.

Target hardness or strength is controlled, as a general rule, by the percentage of limestone used. The greater the percentage of limestone, the tougher the target. Targets are tested for strength on a specially designed drop tester. The target is spun so as to provide the same centrifugal force as would be provided in throwing the target from a trap, where it exits spinning so as to be stable in flight. A small steel ball is dropped from an appropriate height to strike on the dome.

The pitch used in making targets contains certain residual chemicals typical of the carbolic acid types, which are poisonous if ingested. People do not ordinarily eat targets, but pigs have been known to when they have been turned loose on a field where trap or skeet clay targets have been thrown. These fragments are poisonous to the pig, which if it eats any quantity, does not survive.

It has been the custom for many years to place a warning about this environmental pollution on the target carton. No good substitute for pitch seems to have shown up. The warning is still very valid.

Several small hand-operated target machines have been developed and sold. These were designed to use target fragments recovered from trap and skeet fields. The fragments are thermoplastic and generally quite reusable; however, caution must be exercised not to overheat the pitch. Hot pitch constitutes a fire hazard, a burn hazard, takes too long to cool if overheated, and suffers some degradation in continued overheating.

CHAPTER VI
PRIMERS AND PRIMING

Just as no gasoline engine will run well, or run at all, with defective spark plugs, no cartridge will fire without a good primer. However, whereas as engine in need of a tune-up is mostly an annoyance, a misfired cartridge caused by a defective primer cancels out the best of cases, bullets, powder and loading, and, if it happens at the wrong time, leaves a missed target, an empty pot, or even a cancelled life.

This chapter is one of the most extensive in this book, and with reason. Primer making is the most critical step in ammunition production, requiring a quality level that sits on the right hand of perfection. Further, it's not just enough to make a perfect primer, it must be made safely and economically.

Every step must be taken to develop a process with inherent, foolproof uniformity and quality and to protect the worker from even his or her own carelessness as well as from potential hazards.

Hence, the extent and detail in this chapter.

Chemicals and Chemistry

One of the more closely guarded secrets in the manufacture of ammunition has been the manufacture of the primer. Most secret is the production of some of the ingredients in the explosive mix.

The layman, when asked even today what a primer consists of, is apt to answer, "Fulminate of Mercury", which is no longer so.

As a matter of fact, mercury fulminate was discarded as a military primer before 1900. Commercial manufacturers last used it in special purpose ammunition nearly 30 years ago.

In hot, wet climates, fulminate decomposes too fast to give a satisfactory shelf or service life, leading to misfires. Mercury amalgamates with the metallic components of brass, weakening the metallic structure. Plating of primer components is necessary.

Fulminate, when dry, is very dangerous to handle. And today, most of all, there is great public hue and cry over any mercury contamination of the environment. (Which leads one of my generation to wonder how we have survived our childhood bombardment with Calomel. Calomel [mercurous chloride] used to be prescribed for almost anything from coughs and colds, to pimples on the belly.) It isn't the mercury in the primer that causes the public concern. It is the mercury wastes and losses in fulminate handling.

That mercury fulminate might be useful as a priming charge was recognized in the early 18th century. It was 1805, however, before the Rev. James Forsyth mixed it with potassium chlorate as the priming mix in his "scent bottle" locks, and it was 10 years after that before LePage, in Paris, used pure mercury fulminate as a primer. In 1822, Joshua Shaw, an Englishman living in Philadelphia patented the percussion cap as we know it today, again using pure fulminate as an igniter.

Fulminate, alone, was a good priming compound as long as the sole propellant was blackpowder. However, with the advent of smokeless powder, the situation changed. Smokeless powder needs a more complex ignition system to be ignited reliably. For many years, fulminate was a part of that system, acting as an initiator, but back a good many years ago the drawbacks of mercuric priming, including one not mentioned before—cost—were recognized. For these reasons, and because better types of priming have been developed, mercury fulminate is no longer popular in the better primer circles. It is fair to note that for many years after the lead styphnate primer was adopted, Western continued to load 7.62 mm NATO, .30-'06, and .300 H&H Mag. match ammunition with the Western 8½G, fulminate-chlorate primer. The simple reason was that the 8½G always gave better accuracy, on the average, than did ammunition using styphnate priming.

The smokeless powder primer formulation hinges around the choice of the initiator. The initiator is a primary explosive, one needing only a blow or a spark to set it off.

Today the two most widely used initiators are basic and normal lead styphnates. Use of these two compounds began in the early 1930s. With the adoption of the styphnates, today's "non-corrosive, non-mercuric" primers came into being.

The history of the modern non-corrosive primer in the U.S. began back in 1932 when Remington got the jump on its competitors by gaining the patent rights of one Edmond von Herz of Germany to make a non-corrosive primer mix using lead trinitroresorcinate, the lead salt of styphnic acid. This mix, under Patent 1859225, filed in January 1929, and issued May 1932, wasn't quite good enough, being too insensitive. A year later, under Patent 1889116, Herz came through with a winner to which Remington also got the rights. The patent was filed in March 1929 in Great Britain.

Remington also had another primer chemist, James Burns, under its wing. His patent, 1905795, issued April 25, 1933, was filed on September 30, 1929 before Herz's.

The key to the sensitivity problem was solved by both chemists.

Burns' patent and that of Herz overcame the problem of the lack of sensitivity of lead styphnate by mixing a small amount of a sensitizer with the styphnate. This sensitizer, commonly called "tetracene," will be discussed later.

With these three patents, and the sensitive, stable, non-corrosive primer mixes to which they led, Remington gained a decided advantage in the marketplace. And they certainly didn't keep this advantage a secret.

Winchester and Western Cartridge Company, then operating as somewhat independent ammunition factories, were stirred into action and began a feverish search for (1) a way around the patents and (2) a non-corrosive initiator to compete with styphnate.

By 1936, the search had resulted in hundreds of experiments, several very unsuccessful short-lived mixes, a fair amount of scrap and returned ammunition, particularly rimfire, and a general feeling of frustration. Lead azide blew the heads off of too many cases. Potassium azinol went bad soon after loading, and the customers weren't happy with the misfires.

While Joe McNutt in the Winchester plant at New Haven worked to come up with an answer, the Western group at East Alton by 1936 was also spending a lot of time working with styphnate. It was quickly found that it was an unpredictable material, sometimes too sensitive and dangerous to handle even when wet, and sometimes the opposite.

It was at this point that, as more hands were needed to experiment, I was switched from my dynamite and cellulose purification projects to the explosives lab. During one entire summer, several of us made batch after batch of lead styphnate under different conditions, testing each batch for hazard.

At this early stage, the testing was primitive but practical. We simply took a small patty of wet styphnate from the reaction beaker, put the sample on a small metal plate and positioned a short length of dynamite fuse so that, as it burned out, it spat a small flame at the pat of styphnate.

Sometimes nothing happened, which was good.

Sometimes the whole pat went up with a bang. Which was not good, and the balance of vicious material in the beaker was carefully destroyed in a bath of caustic. After disposal, one breathed a little freer, and started on a new tack.

It finally became obvious that control of the crystal shape in the styphnate was the key to safety, and by further experiment that something had to be done to the styphnic acid from which the lead styphnate was prepared to modify the crystal shape. A long narrow crystal was more unpredictably sensitive than a shorter, wider one, both being hexagonal when seen under the microscope.

About this time, we had one spectacular accident in the lab. Fred Garfield, just before the noon whistle blew, had finished with a larger than usual batch of styphnate, had taken his safety goggles off in preparation for the dash to lunch. He gave the bucket in the sink one last stir for luck. The "luck" turned out to be bad.

With more of a "whump" than a bang, a small portion of the total explosive blew. The bottom of the bucket went through the sink. Fred got a face full of the bucket's unexploded contents. Most of the remainder splattered the ceiling and walls of the lab. Since this stuff is a bright yellow dye, the whole area (Fred Garfield included) was a uniformly monochromatic brilliant yellow.

At first, it was difficult to see how badly hurt he was, but he seemed to be in one piece and conscious.

He did have two other immediate problems. Unless defused, dry, he would have been a living bomb; wet, he would be rapidly absorbing poisonous lead compounds through sensitive nasal tissues or by swallowing. The first action in the lab was to clear the poisonous lead compound from nose, mouth and ears, and out of his hair and off his clothes before it dried. His eyes were rinsed out but not touched as there was immediate fear as to permanent damage. Then we got him a hospital. As it turned out, damage—to Fred and to the lab—was slight and not permanent. It does go to show that styphnate can be tricky stuff.

At any rate, the struggle went on until the late 1940s, when Remington's patent rights ran out. In the interim, during WWII, and up until 1946, a reasonably successful substitute wet mix (developed in 1940) using diazo-dinitrophenol was used in Western and Winchester's military primers. DDNP is as sensitive an initiator as mercury fulminate and more stable, though it is little less stable than lead styphnate. DDNP endures almost indefinitely under normal storage.

Means were found to control the final styphnate crystal size and shape by controlling the nitration in the making of styphnic acid. With the explosive chemists' attention concentrated on the styphnate-tetracene initiator as a starting point, excellent mixes for all purposes were developed.

In the five ammunition plants in which I have worked, and a sixth which I have visited, the rimfire mixes are much alike, all using lead styphnate-tetracene combination as the initiator.

Chemical Components

A priming mix has many ingredients beyond the initiator. The total effect of these is to create a situation in which potential energy can be kept on tap for years, waiting only for a blow from a firing pin to jump into action and develop a burst of incendiary gas that ignites the powder. The styphnate initiator provides a part of the hot gas, but is too violent and quick acting to used alone.

Therefore, in order to get enough hot gas, a fuel must be provided and to burn the fuel there must be a source of oxygen.

In U. S. practice, where the priming mix is usually loaded into the primer wet, a binder is added and the whole is desensitized with water until the priming is safely in the rimfire shell or primer cup.

In the rimfire cartridge, there is still another ingredient, called a "frictionator", which makes sure that the firing pin blow irritates the initiator sufficiently to explode it.

As a whole, then, the primer doesn't really detonate, only its initiator does that. The rest of the mix burns, but at a very high rate of speed. The initiator heats up the other ingredients, using up its own oxygen and igniting the fuel-oxidizer combination of ingredients.

Back a good many years ago, the military recognized the short life of fulminate. It didn't permit the long-time storage of ammunition or the building up of ammunition reserves. The Army changed to priming mixes containing no fulminate, but using sulphur, potassium chlorate, and antimony sulfide. The last of this series used lead sulfocyanate in place of sulphur, plus a small amount of TNT and a binder. This most recent mix is known generally within the shooting fraternity as the FA 70 mix, "FA" standing for Frankford Arsenal. Actually, the mixture was developed by the explosive chemists at Winchester as their "35NF". The formula was given to the military during World War I. The FA 70 mix was extremely stable in storage, and was quite safe to handle in charging primers. None of the ingredients was by itself explosive, only the dried mixture. The drawback, was that, when the potassium chlorate gave up its oxygen in firing, it left a salty residue of potassium chloride, first cousin of sodium chloride—common table salt. The salt if not removed immediately after firing by careful washing and cleaning, did a beautiful job of rusting the barrel. Since not many people like rusty barrels, the FA 70, however good ballistically, never got as popular as today's non-corrosive primer mixes.

Varied chemicals are used in the various mixes, depending somewhat on the end results required, as well as on the choice of the manufacturer. The chemicals can be divided into seven categories:

1. The INITIATOR. As discussed earlier, the most common in use today is lead styphnate, and principally "normal" lead styphnate. As a generality, the sample mixes listed in Table 4 (See p. 85) use either Normal or Basic styphnate may be used in the proportions shown. Unless prepared in a form having a definite crystalline form rather than the long needle-like form most common with basic styphnate, the basic is a little more difficult to handle in charging.

For reasons discussed earlier, mercury fulminate has virtually passed from the picture. With today's concern with mercury pollution, plus its other drawbacks, the passage will not be much lamented.

There are other possible initiators, some quite exotic and some more dangerous to handle, and some much more costly to make. The best current choice is lead styphnate.

2. The SENSITIZER. Styphnate by itself is a little too phlegmatic when surrounded by the other priming chemicals, and needs a firing pin blow rather heavier than most rifle or pistol mechanisms are prepared to administer. Another more sensitive priming explosive, called a sensitizer, is added to the styphnate to make the mix properly irritable.

Almost universally, an uncommon chemical, known formally by the tongue-twisting name guanylnitrosoaminoguanyltetracene, but more informally and conveniently known as "tetracene," is used. This tetracene has nothing in common with the antibiotic "Tetrazene", except that both are complex chemicals. It, in fact, would seem that the two work in somewhat opposite directions, one heals, and the other definitely doesn't. It takes only a small amount of non-medicinal tetracene in the mix to make sure that the initiator goes to work.

3. The OXIDIZER. These provide oxygen to burn up the fuel provided so as to supply a satisfactory volume of incandescent gas to light up the powder. Potassium chlorate would be a splendid oxidizer, as it is fairly bursting with oxygen ready to go to work, but it will be remembered it leaves behind a salty residue guaranteed to rust even stainless steel barrels if not removed promptly. The most commonly used oxidizer is barium nitrate. Stable in storage, non-reactive in either a wet or dry state with the other chemicals, barium nitrate gives up its oxygen quite readily, and the by-products are non-corrosive.

Lead nitrate has nearly the same characteristics as barium nitrate, but is a little more reactive with some of the other priming ingredients. In fact, in wet form it can react with lead hypophosphite to form a sensitive primary, initiating, explosive complex when dried. One of the mixes to be discussed later uses this reaction. Lead nitrate is about four times as soluble in water as barium nitrate, which must be taken into account in wet mixes when any excess water must be removed before charging.

Lead peroxide (or dioxide), PbO_2, is an excellent oxidizer, giving up its oxygen very readily, more readily in fact than lead nitrate and at a lower temperature. However, by weight PbO_2 has only 13% oxygen vs. 20% for lead nitrate. Principal advantage of the dioxide as an oxidizer is that its oxygen is released earlier and faster, speeding up the primer action.

4. The FUELS. These are what the oxygen in the oxidizers burn. They provide a more lasting flame than that produced by the initiators for powder ignition.

Surprisingly, the lead styphnate when exploded is oxygen deficient, and therefore acts partly as a fuel as well as initiator when oxygen released by the heat of the explosion becomes available.

The most commonly used fuel is antimony sulfide, an easily oxidized chemical, which finds wide use in the production of matches and for the same purpose. It is a very stable chemical.

Lead sulfocyanate burns more easily, but is not quite as stable and is a bit more reactive than antimony sulfide.

Calcium silicide is another fuel in fairly common use. It oxidizes well, but is difficult to use in some mixes because of its tendency to react with some of the other chemicals, hardening the mix and reducing sensitivity in the finished dried primer.

Aluminum in a finely powdered form also makes a good fuel when used in small quantities along with other fuels. The fiery particles of burning aluminum are blown into the powder charge by the primer blast, aiding ignition still further.

On an exceptionally large powder charge in a large case, such as .50 cal. military cartridge, the amount of initiator is reduced, to be replaced by aluminum, up to 10%, and additional barium nitrate, to develop a greater amount of hot gas for powder ignition.

5. The FRICTIONATOR. Generally not necessary in centerfire primers, but definitely needed in rimfire cartridge cases. The frictionator provides sharp corners against which the particles of sensitizer and initiator are forced by the movement of the primer cup or case rim under the firing pin blow. This assures more positive and rapid compression and rupture of some explosive crystals. It is partly this breaking of crystal which starts the primer action.

Ground glass is the common frictionator. Some naturally occurring glassy minerals may be used, but the best choice is borosilicate glass. For some reason, probably having to do with particle shape or maybe friability or hardness, ordinary glass doesn't do quite so well. Sensitivity suffers to an appreciable degree in rimfire with the use of commons glass. "Pyrex" dishes are made of one type of borosilicon glass, which is not quite of the best composition for primers, being a little too hard.

6. The BINDERS. In most primers, the mix is not self-adherent when dry, and some sort of binder must be used to hold the mix in place. Various gums, starches and similar materials may be used. They must be non-reactive with the other chemicals when wet, and stable when dry, and must not interfere with the crushing of the mix under the firing pin blow. Two of the most common gums are gum arabic and gum tragacanth. The two gums are normally used together, in a ratio of about two to one arabic to tragacanth. The gum tragacanth has use in the pharmaceutical business where the jelly formed by gum and water is commonly used as a lubricant on various things, including the doctor's delving digit. In priming mix, the lubricity of the wet tragacanth helps make the mix a little more mobile in charging, while the dried gum acts as a binder.

Polyvinyl alcohol has some application as a binder. Being an alcohol, it is soluble in water, yet dries out again to a solid inert binder, which doesn't absorb water readily thereafter.

7. OTHER MATERIALS. Certain other materials, not classified above, have been used in some priming mixes.

It is common, in order to help inspection of the primed rimfire shell, to include a coloring material in the mix, Prussian blue. Not that oily pigment used by the painter as coloring or by the machinist or gunsmith in checking fits—the oil vehicle would kill the mix—but dry ferric ferricyanide. The blue together with the yellow of the styphnate makes a green contrast in the shell so that missing priming is easier to spot. Vegetable food colorings may also be used, blue again seeming to do the best.

Table 4: Common Priming Mixes

FORMULA		I	II	III*	IV	V	VI	VII	VIII	IX	X
Initiator	Lead Styphnate	40	45	40	37	37	38	40	40	45	36
Sensitizer	Tetracene	2	4	2	4	4	2	4	4	3	3
Oxidizers	Barium Nitrate	30	22	—	30	32	39	30	34	42	40
	Lead Nitrate	—	—	30	—	—	—	—	—	—	—
	Lead Peroxide	—	7	—	—	—	5	—	—	—	—
Fuels	Antimony Sulfide	—	—	—	25	15	5	16	16	—	11
	Lead Sulfocyanate	8	—	8	—	—	—	—	—	—	—
	Calcium Silicide	—	—	—	—	—	11	—	—	—	10
	Aluminum	—	—	—	4	7	—	5	—	—	—
Frictionator	Ground Glass	20	22	20	—	—	—	—	—	7	—
Others	PETN	—	—	—	—	5	—	5	6	3	—
		100	100	100	100	100	100	100	100	100	100

* U.S. Patent No. 1,905,795-Remington Arms Co., Apr. 25, 1933.

Some use is also made of pentaerythritoltetranitrate, more commonly known as PETN, as well as TNT, and occasionally diazodinitrophenol, DDNP, all of which are military explosives. The function of these materials in the primer is not so much as an explosive as it is a source of heat and energy, except that DDNP is also a sensitive initiator, about as sensitive as mercury fulminate, as mentioned earlier. Some use is also made of nitrocellulose in finely divided form for the same purpose.

Priming Formulas

Look now at the priming formulas in Table 4, and note the wide variety of compositions and amounts of the same ingredients. The figures shown are percentages of the ingredients on a dry basis. In formula III, the binder is provided by the reaction between lead nitrate and lead sulfocyanate, forming a complex compound which hardens like cement. All of these mixes are handled wet to make them insensitive enough to handle safely.

Binders—In the above formulations, with the exception of III, the amount of gum binder used approximates 1% of the total weight, with the ratio of arabic to tragacanth about .7 to .3. If polyvinyl alcohol is used, the amount can vary from .2% up to as much as 1%.

Formulas I, II and III are rimfire mixes. Each makes considerable use of the styphnate as fuel. They represent three different companies' choices for the same final purpose.

IV is a mix typical of that used for small rifle and pistol primers, containing much more fuel and oxidizer than the rimfire mix.

V is a mix typical of large rifle primers where more aluminum gives better ignition in the larger powder space.

VI shows the use of calcium silicide as a fuel together with antimony sulfide and the active oxidization provided by the lead peroxide.

VII is a mix which works well with shotshell primers. PETN helps ignition of the fast burning, low pressure powder. This mix also works well in large rifle primers.

VIII is the mix used in small rifle primers.

IX is a large pistol primer mix, principally for .45 auto. where there is a large powder space with low loading density.

X is an alternate large rifle mix, low in styphnate, high in fuel and oxidizer.

Earlier mention was made of the Win. 35NF/FA 70 mix; its composition was:

Potassium Chlorate	$KClO_3$	53%
Antimony Sulfide	Sb_2S_3	17%
Lead Sulfocyanate	$Pb(SCN)_2$	25%
TNT		5%

To which, of course, is added a binder and water, since the mix is charged wet.

The Western 8½G primer, mentioned earlier in this chapter, had the following composition:

Mercury Fulminate	31.6%
Potassium Chlorate	42.1%
Antimony Sulphide	26.3%

In this mix, the chlorate in close contact with a finely divided oxidizable material makes a combination that is its own initiator. The antimony sulfide and the lead sulfocyanate are both fuels.

Every boy who ever shot a cap pistol remembers how the little round spot in the middle of the cap went bang. What he probably didn't have much use for knowing was the potassium or sodium chlorate, red phosphorus, sulfur and charcoal were the active materials, certainly able to initiate the bang when the hammer hit. Back when I had time to shoot a few muzzle-loaders, percussion caps were sometimes a little hard to come by, and more than once the common toy cap-pistol cap did the job very well. Of course, there was a greater than usual problem fighting rust, but cleaning a gun never seemed a very onerous chore anyhow. The point is that in this simple device we do have a basic primer complete with initiator, fuel and oxidizer.

Historically, back in 1845, the same idea in the Maynard tape lock was used in converting flint locks to percussion.

Priming Chemistry

Of the priming chemicals shown, several are not usual "shelf" items in any chemical supply house and some are too dangerous to ship. These must, therefore, be produced "in-house" in any priming operation.

These may be normally purchased:

Barium Nitrate	$Ba(NO_3)2$
Lead Nitrate	$Pb(NO_3)2$
Calcium Silicide	$CaSi_2$
Aluminum	atomized
Antimony Sulfide	Sb_2S_3
Lead Dioxide	(but is easy to make as well) PbO_2

PETN (shipped as an explosive) or in Detonating Cord
Polyvinyl Alcohol, molecular weight approx. 8000
Gum arabic and gum tragacanth
Prussian blue
Ground glass
Borosilicon

These are normally made in house:

Lead Styphnate	Tetracene
Lead Peroxide (Dioxide)	Lead Sulfocyanate
Lead Hypophosphite	

Now, as to producing the various priming chemicals not likely to be found in drug or chemical supply houses, one must delve a bit into chemistry. Most of the processes are reasonably straightfor-

ward and within the province of most anyone willing to follow a recipe accurately, being careful about weighing and measuring quantities exactly and keeping temperatures in control.

Lead Dioxide

Although this material can be purchased, there are restrictions on shipment because it is a powerful oxidizer. It is not very difficult to prepare.

One starts with lead oxide, litharge, PbO, or another common compound, red lead, lead orthoplumbate, Pb_3O_4. By reaction with laundry bleach, sodium hypochlorite, NaOCl, either compound is further oxidized to the dioxide, sometimes called lead peroxide.

As the chemist would write:

$$PbO + NaOCl \longrightarrow PbO_2 + NaCl$$

or

$$Pb_3O_4 + 2NaOCl \longrightarrow 3PbO_2 + 2NaCl$$

As to proportions, the molecular weight of PbO is approximately 223 while that of NaOCl is 74.4, so that on a smaller scale, in theory one pound of litharge would require a proportionate .29 pounds of NaOCl. However, in practice, an excess of NaOCl would be used to speed up the reaction and to make sure all of the PbO was converted to PbO_2.

When using laundry bleach as a source of sodium hypochlorite, it must be remembered that the concentration of NaOCl in the bleach is only about 5% of the total weight. The concentration is usually marked on the bottle. Therefore, at a concentration of 5%, some 5.8 pounds of bleach would be needed and, with the above-mentioned need for an excess, about double the theoretical quantity, say 12 pounds, would be used.

Similarly, with red lead (Pb_3O_4), molecular weight 685.6, as a starting point, three molecular weights of hypochlorite, 223.2, would be needed. Again in proportion, one pound of red lead would need .325 pounds of NaOCl, or in the case of bleach, 6.5 pounds. Again, an excess would be used as with PbO, double the quantity being about right. The unused excess is simply wasted. The reaction goes faster with PbO.

The reaction is simple. Find a stoppered jug or jar large enough to hold the quantities desired, place the litharge or red lead in the receptacle, add the bleach, shake or stir vigorously from time to time and wait until the entire precipitate in the bottom of the jar has turned to a dark brown or black color.

And, don't wait around for things to happen. The reaction takes many hours at room temperature. Because the very heavy oxide settles quickly into a dense cake, it is necessary to stir the mixture thoroughly from time to time so that the hypochlorite stays in intimate contact with all of the oxide.

One other thing, remember that bleach when opened tends to lose its strength through loss of chlorine, therefore an additional amount of bleach may be needed to compensate, if the bleach is not fresh.

After the reaction is complete, the PbO_2 needs thorough washing with clear water.

Allow the dioxide to settle. Pour off the reaction liquor, add a large amount of water, stir thoroughly, settle. Pour off the water, and repeat several times.

Lead dioxide is only slightly soluble in water, and losses through washing will be negligible. After washing, dry the dioxide.

Lead Sulfocyanate (Thiocyanate)

Here's another compound prepared without much fuss. Preparation is based on a simple exchange reaction between lead nitrate and sodium sulfocyanate, NaSCN.

$$Pb(NO_3)_2 + 2NaScN \longrightarrow Pb(SCN)_2 + 2NaNo_3$$

Proportionately, the molecular weight of lead nitrate is 331.2, while that of sodium thiocyanate is 81.1, therefore with one pound of lead nitrate one would need .25 pound of sodium thiocyanate, and the end product would be a little less than one pound of lead thiocyanate.

One might note a little confusion here in names: "sulfocyanates" and "thiocyanates" are the same thing. The more common usage is "thiocyanate," either sodium or lead.

In this reaction, the lead nitrate is dissolved in water. Heating the water will hasten solution. One pound of nitrate in about a gallon of water is a good working concentration. A small amount of acid, nitric, sulfuric, or hydrochloric, is added to the water to make sure the solution is not alkaline.

The sodium thiocyanate, $\frac{1}{4}$ lb. for 1 lb. lead nitrate, is dissolved in a half pint of water. This solution is stirred into the lead nitrate solution. Lead thiocyanate, which is insoluble in water, will immediately precipitate out and settle to the bottom. The clear liquor above, now containing sodium nitrate (saltpeter) may be decanted off. Plain water may next be poured into the reaction container, stirred up with the lead compound, which is then allowed to settle, and the water poured off. Several washings will assure the purity of the thiocyanate, which may then be dried and stored for use.

Lead Hypophosphite

Now, this one is a bit tricky. Lead hypophosphite, $Pb(H_2PO_2)_2$, is formed by the reaction between lead nitrate and calcium hypophosphite, $Ca(H_2PO_2)_2$. But, when lead nitrate and lead hypophosphite come together, as mentioned earlier, they form an explosive compound, lead nitrato-

hypophosphite, $Pb(H_2PO_2)NO_3$. Therefore, the trick is to add lead nitrate, in a weak solution, to a solution of the calcium compound. The lead hypophosphite, being essentially insoluble in cold water, precipitates out as a white substance, while the remaining calcium nitrate stays in solution. This way, since the lead nitrate is immediately reacted with the calcium hypophosphite, none remains present to react with the newly formed lead hypophosphite.

The reaction goes as follows:

$$Pb(NO_3)_2 + Ca(H_2PO_2)_2 \longrightarrow Pb(H_2PO_2)_2 + Ca(NO_3)_2$$

Molecular weights are 331 for lead nitrate, 170 for the calcium hypophosphite, so that for 500 grams of lead hypophosphite, one would need 252 grams of calcium hypophosphite and 491 grams of lead nitrate.

The calcium compound is not very soluble in water, about 15 grams in 100 cc of water constituting a saturated solution, and it's slightly less soluble in hot water. So, for dissolving 252 grams of calcium hypophosphite, one would need at least 1680 cc of water. Lead nitrate is much more soluble, 100 cc water dissolving about 50 grams at normal temperatures, but, since the solution should not be concentrated, the 491 grams should be dissolved in about two liters of water.

After precipitation, the newly formed lead hypophosphite should be thoroughly washed with clear water, then dried.

Neither of these three materials is explosive, and none needs any special storage, except one must remember the strongly oxidizing qualities of lead dioxide.

A note on PETN: The simplest source when relatively small quantities are needed is Primacord. Simply split the cord lengthwise and shake the PETN out, screen it to get rid of foreign material, dampen it down and store in a well stoppered bottle. PETN is dusty, and the dust is somewhat poisonous being a vasodilator, as well as hazardous.

Last, we come to the key chemicals, all three explosive, although one, tri-nitro resorcinol, or styphnic acid, is much less sensitive than the other two, tetracene and lead styphnate.

Tetracene

The preparation of tetracene is a more complicated chemical procedure, but still not difficult.

Remember always that tetracene is a very sensitive, primary detonating explosive when dry, and it must be kept wet until ready for use. Water thoroughly desensitizes tetracene.

The reaction involves a non-common complex chemical, aminoguanidine bicarbonate, plus sodium nitrate and acetic or sulfuric acid.

Actually, three reactions take place. Chemically, it goes like this:

1. $NC_2C(:NH)NHNH_2HCO_3$ (aminoguanidine bicarbonate) + $HOOCCH_3$ (acetic acid) — $NH_2C(:NH)NHNH_2$ (aminoguanidine) + water + CO_2

2. $NaNO_2$ (sodium nitrate) + $NOOCCH_3$ (acetic acid) — HNO_2 (nitrous acid)

3. 2 $NH_2C(:NH)NHNH_2$ (aminoguanidine) + 2 HONO (nitrous acid) — $NH_2C(:NH)NH{-}N{=}NC(:NH)NHNHNO$ (tetracene)

These equations are not "balanced" in the chemical sense as the nonessential by-products, water, carbon dioxide, and sodium acetate are not listed, but the principal reactions are as shown.

To prepare approximately one kilogram of tetracene, the exact amount depending on the yield, one starts with 1440 grams of aminoguanidine bicarbonate, 670 cc glacial acetic acid, and 1700 grams of sodium nitr*i*te, not nitr*a*te.

Place the 1440 grams of aminoguanidine bicarbonate in 20 liters of water, stir to place the insoluble compound in suspension and heat to 30°C. Continue stirring and add the acetic acid slowly to keep the reaction from foaming over.

Dissolve the sodium nitrite in 3.5 liters of water, heat also to 30°C and add to the aminoguanidine solution. Add enough additional water to bring the mixture up to a final volume of 29 liters, making sure the temperature at that time is 30°C ± 1°.

Now, allow the mixture to sit for 24 hours while the reaction is taking place. The tetracene will slowly settle out.

When the reaction is complete, carefully decant the liquid off, washing the tetracene down the side of the reaction vessel. Add clear water, stir, and filter on a Buckner funnel with vacuum. Wash at least six times with clear water to remove all the acetate. On the last filtration, continue until water has almost stopped dripping. At this point, an approximate yield may be obtained.

To estimate the yield, weigh the wet filter cake, and assume 40% water in the cake. Yield should be between 900 and 940 grams, dry weight.

Copper, if present in even the smallest amount, will act to prevent the formation of tetracene. The expected reaction will simply not take place. Therefore, no copper or brass vessel can be used, no copper stirrer, and no copper ions in the water or chemical can be permitted.

The filter cake of tetracene should be stored fully wet in a sealed container until ready for use.

Styphnic Acid

Now we come to a more complex chemistry, the nitration of resorcinol to form tri-nitro resorcinol, or styphnic acid.

Resorcinol is a close relative of carbolic acid. Picric acid, a well known high explosive, is made by nitrating carbolic acid, also known as phenol.

Both styphnic acid and picric acid are brilliant yellow dyes, among other things. Both are fairly strong acids and tend to form very explosive salts, if they come in contact with various metals. The thought here is that stainless steel, rubber, or plastic are the safest materials for handling and storage. Copper reacts quite slowly with styphnic acid and could have some temporary use, but it is not recommended.

The nitration process takes place under highly acid conditions, both concentrated sulfuric and nitric acids being involved. The longest lasting nitrator is one made from Duriron, but Duriron, besides being expensive, has one serious drawback. It is a very brittle material which won't stand much abuse from either mechanical strain or thermal shock. Sudden temperature changes may cause a Duriron vessel to crack, creating a loose acid problem akin to that encountered by the man who invented the universal solvent—what to keep it in? A flow of hot nitrating acids will eat its way through most anything, flesh included, and a mop won't help.

Nitration is in two steps. The first step is sulfonation with sulfuric acid, which prepares the way to hook the nitrogroups onto the benzene ring of the resorcinol. Then comes the actual nitration with nitric acid. The chemical reaction is illustrated in *Figure 37*.

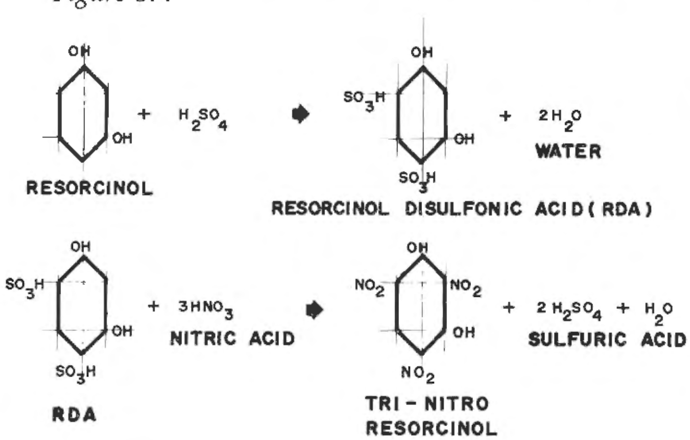


Figure 37

It was mentioned earlier that something had to be done to the styphnic acid in order to make the final product, lead styphnate, safe to handle as an explosive.

What is done is to make the styphnic acid slightly impure by adding an adulterant during the sulfonation stage.

Various adulterant chemicals, including catechol, glucose, phenol, acetic acid, trioxane, and sodium nitrate, among others, are mentioned in the patents. All, in small quantities, affect the final shape of the lead styphnate crystal, by making it longer, shorter, wider, thinner, etc.

The safest crystal appears to be a thin hexagonal plate of small size. Large and irregular crystals of other shapes, particularly elongated shapes, appear to be the most sensitive.

Sodium nitrite, or rather the presence of nitrous acid in the sulfonation step, creates this respected crystal shape quite well.

In sulfuric acid the addition of sodium nitrate creates nitrous acid, and in sulfonation of resorcinol, the resorcinol first reacts with the nitrous acid to form a variety of compounds which are themselves nitrated in most cases. These extra nitrated compounds by their presence, in some way not clearly known, affect the final shape of the lead styphnate crystal.

In the sulfonation and nitration of resorcinol, as in many other reactions, careful control of temperature and time are necessary. Both yield and quality of product are influenced by either too high or too low temperatures or by variation in time allotted to various steps.

In the laboratory, of course, any chemist knows how to control temperature by setting the reaction beaker in a large container of water whose temperature can be adjusted. Industrially, the Duriron vessel or nitrator is jacketed and supplied with either hot or cold water circulation.

A satisfactory nitrator can be made of types 304, 316, or 430 stainless steel, but the life of the nitrator will be somewhat less than that of a Duriron nitrator of the same thickness, due to constant corrosion during the nitration process. Indeed, nitrator life can be predicted depending on metal thickness and hours of exposure to acid.

The nitrator must be therefore jacketed to control temperature, equipped with an agitator, also stainless, and must be covered and vented to the outside, due respect being paid to atmospheric pollution. It is uncomfortable, as well as unhealthful, to breathe nitric acid fumes, either indoors or out.

Suitable precautions must be taken to protect the operator from acid splashes or spillage. Goggles, head covering, rubber aprons, rubber gloves and adequate foot covering are musts. And a handy shower for the operator to jump under is another must. It is not only a contributor to peace of mind, but also a great preventer of serious injury from acid burns. It's a lot easier to change wet clothes than burned skin.

Which reminds me of the benefits of instant application of water to acid burns.

Back in my Junior College days, we had one lone

girl in the chemistry class, and it was a small comradely group. One fine spring day, the girl was sitting on a lab stool busily swirling a Florence flask holding a really stout-hearted mixture of concentrated sulfuric acid and a powerful oxidizer, potassium dichromate. The mix is called "cleaning solution" and is guaranteed to tidy up most any dish it doesn't dissolve.

We heard a gasp and looked up to see that the flask had burst and dropped its angry contents right in her lap. the cloth was rapidly dissolving and the seat of motherhood was about to be invaded.

Without ceremony, since Margaret was in a bit of a dither, two stalwarts leaped to the rescue, ripped off the skirt, sat her bodily in the deep sink and turned the water full force in her lap.

She wasn't even singed, but had to go home pantyless in a borrowed raincoat, face redder than her bottom, embarrassed over the public exposure.

This is one time where the old rule of "don't add water to acid, but acid to water" didn't hold. One very important thing to remember here, an emergency shower facility is a *must* wherever concentrated acids are handled.

A typical nitration proceeds like this:

First the chemicals:

102 kg. 66° Beaume concentrated sulfuric acid, electrolyte grade
10 kg. resorcinol, technical grade
110 grams sodium nitrite, technical grade
41.4 kg. (2.3 liters) 70% nitric acid, technical grade.

The sodium nitrite is somewhat deliquescent and doesn't flow or sprinkle well, unless oven dried just prior to use. Dry it, put it in a well stoppered bottle, until time comes to put it in the nitrator.

Next, put the 102 kg., 64.6 liters, of sulfuric acid in the nitrator. Start the stirrer. Over a period of 1-½ hours, gradually add the resorcinol. Beginning 10 minutes after adding the first resorcinol, and over a period of 30 minutes, gradually sprinkle in the dry sodium nitrite while continuing to add the resorcinol. It's easier to mix the nitrite with the resorcinol just before adding the resorcinol to the nitrator. That way the small amount of nitrite is better distributed.

Over the next two hours, bring the nitrator temperature up to 60-63°C. Hold at this temperature for one hour. Then cool to a temperature of 32-35°C over a period of 2½ hours. The resorcinol has now become resorcine disulfonic acid (RDA). The RDA can be held in the nitrator overnight or longer, if time runs out for the day. Unless one is in a hurry, overtime to finish the nitration isn't called for.

Now for the nitration, which starts with the RDA in the nitrator at 32-35°C. Next comes the nitric acid, 29.3 liters of it fed in a rate of one liter in 16 minutes. The delivery tube for the acid should be just below the surface of the liquid. Less fumes are produced, that way.

During the addition of the first 22 liters of nitric acid, the temperature should be kept within the 32-35°C range by cooling the jacket. For the balance of the addition, the temperature will no longer tend to rise, and the water in the jacket must be warmer to keep the temperature at the specified level.

The acid addition continues at the same rate until all has been added, about eight hours being required totally.

Nitration is now complete, and cooling water may be turned on in the jacket to bring the contents in the nitrator down to normal room temperature before dumping.

During the cooling stage, one additional step is needed.

At this point, it is well to reflect that the nitrator should have a dump valve at the bottom, as bailing out a mixture of acid and TNR from the top of the nitrator is both dangerous and messy.

So, the dump valve is opened a little, and a liter or so of the contents is drawn off into a pitcher (acid-proof, of course). The material in the neck of the dump valve got out of the mainstream of events and may not have gotten the full nitration treatment. Pour the pitcher of unreacted material slowly back into the nitrator, and no potential TNR will be wasted, as the acid in the nitrator will take care of it.

Now draw off the nitrator contents into an acid-proof filter of the open, stone type, vacuum equipped. The spent acid drawn through the filter then goes to appropriate disposal as waste, treatment depending on local laws regarding acids, nitrates, and colored effluents.

Moving the filter aside, the nitrator is washed down with 10 to 15 liters of water drawn out into a separate container. This acid water is used for the initial washing of the TNR filter cake. The nitrator is then washed out thoroughly to be ready for the next nitration.

The set-aside waste water from above is slowly poured over the surface of the filter cake, which is stirred up while so doing, again under vacuum. This water, being strongly acid, must also be neutralized for disposal.

The filter cake is then washed down with tap water for at least five minutes and then vacuumed to dryness for another 15 to 20 minutes. The filter cake is then removed and slurred up in at least 20 liters of water and refiltered twice more. The finished TNR is then bagged up in plastic bags and stored wet.

Lead Styphnate

Starting with TNR, the next step is to make the major priming ingredient, lead styphnate.

Actually, there are two kinds of styphnate, normal and basic (See Fig. 38).

As will be noted, the molecule of basic styphnate has two lead atoms, the normal but one.

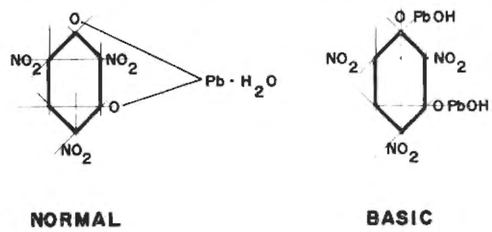


Figure 38: The Two Styphnates

The molecular weight of normal styphnate plus its molecule of water hydrate is 468.2 and, with the molecular weight of lead being 207.2, the percentage of lead in the compound is 44.2. On the other hand, the molecular weight of the monohydrated basic styphnate is 677.4, so the percentage of lead is 61.1.

By weight, then the normal styphnate has the higher explosive content.

Both styphnates are deficient in oxygen when decomposing at the time of firing, so that both act as fuels, as well as initiators. With the simplest products of combustion, the styphnate decomposes to a mixture of H_2O, N_2, CO_2, PbO: water, nitrogen gas, and lead oxide, respectively.

A molecule of basic styphnate, $C_6N_3O_{10}H_3Pb_2$, ideally decomposes to $6CO_2 + 1\frac{1}{2}N_2 + 1\frac{1}{2}H_2O + 2PbO$. Balancing the oxygen needed, $14\frac{1}{2}$ units, against the 10 furnished by the styphnate itself, there are $4\frac{1}{2}$ oxygen units lacking. Hence, the oxygen deficiency to be made up by the oxidizer.

Similarly, normal styphnate, $C_6N_3O_8HPb$, burns, decomposes or oxidizes to $6CO_2 + 1\frac{1}{2}N_2 + \frac{1}{2}H_2O + PbO$. Here $13\frac{1}{2}$ units of oxygen of needed against 8 present. The remaining $5\frac{1}{2}$ must be furnished by the oxidizer.

Basic styphnate usually appears in the form of long yellow needles, like straw in a strawpile, and is somewhat fluffy in character accordingly. Primer mixes are a little greater in volume than those made with an equal weight of normal styphnate, which may make some difference if there is a space problem in the primer. Basic styphnate is somewhat safer to make and handle.

Normal styphnate, because of its fatter crystal shape seems to handle better on the charging table in primer mixes, and is more commonly used.

Both styphnates are usually prepared by treating styphnic acid with lead nitrate. Being insoluble in water, the lead styphnate precipitates. But the styphnic acid is also insoluble in water and must first be reacted with some other chemical to form a water soluble salt. Sodium hydroxide, ammonia, magnesium carbonate, and zinc oxide, for instance, all form soluble styphnic salts. Normal lead styphnate may also be prepared by the direct reaction of styphnic acid with lead oxide (PbO), but the lead nitrate route is easier to control.

If one dissolves styphnic acid in a sodium hydroxide solution, and then slowly stirs this solution into a dilute solution of lead nitrate, the basic styphnate is formed. The reaction is similar with the other salts mentioned above.

Starting with one liter of water, dissolve in it 10.7 grams of sodium hydroxide. Add 16.3 grams of TNR, stirring until the TNR has gone into solution, forming sodium styphnate. Now dissolve 70 grams of lead nitrate in 1.5 liters of water. Slowly add the TNR solution to the lead nitrate solution and the yellow needle-like lead styphnate of the basic type will precipitate out and settle slowly.

For normal styphnate, the approach is different and a little more care has to be taken.

The reaction is shown in *Figure 39*.

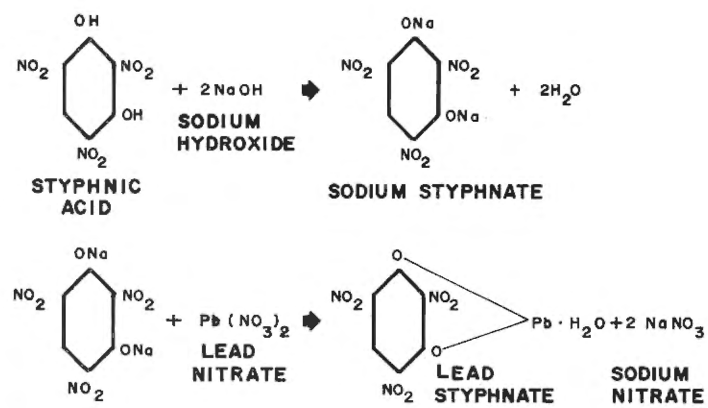


Figure 39

Quantities of materials are as follows:

TNR	500 grams
Sodium Hydroxide	161 grams
Lead Nitrate	850 grams
Acetic Acid	162 grams (154 cc)

The acetic acid (glacial) has no direct part in the reaction, but affects the hydration, and later the dehydration of the lead styphnate.

An excess of lead nitrate, about 25% more than theoretically needed, is used to insure that all the TNR is reacted and that yield is at a maximum.

To start with, the NaOH is dissolved in 225 cc of water. The lead nitrate is placed in 1890 cc of water and heated while stirring to hasten solution. When the nitrate has all dissolved, the glacial acetic acid, 154 cc, is added to the solution. The solution may then be allowed to cool.

The TNR, 500 grams, is placed in the reaction vessel, preferably a rubber or plastic bucket.

Stainless steel is *NOT* recommended for either bucket or stirrer. For some reason, the thin crust of crystals which tends to form where the surface of the liquid meets the bucket and stirrer in a stainless steel vessel tends to be inordinately sensitive and has been the probable cause of several explosions, some fatal.

With the TNR in the bucket, 1900 cc of water is added and stirring begins. While stirring the TNR suspension, the temperature in the bucket is raised to 40-45°C. Obviously, direct heat application is not recommended, unless the operator is looking forward to a short life. The bucket should be in a bath of hot water, whose temperature can be controlled.

The sodium hydroxide solution is now added to the TNR, forming a solution of sodium styphnate. The temperature will rise 10 to 15 degrees, due to the heat of the reaction. Addition of the lead nitrate solution begins immediately and should take place slowly over a period of about 30 minutes.

Soon a marked change will begin to take place. The mixture gets thicker and thicker, until it has completely jelled, and stirring no longer moves the mass. At this point, which is fairly early in the addition of lead nitrate, the temperature in the water bath is raised to 70-75°C, and further circulation of hot water is stopped.

Continuing the addition of lead nitrate without stopping, the gel will slowly start to loosen up and finally stirring will again take place. What has happened is that the initial lead styphnate formed is highly hydrated, but, under the influence of more lead nitrate, dehydration occurs, and the lead styphnate assumes its usual crystalline shape of small hexagonal plates.

Once the gel breaks up and all the lead nitrate has been added, stirring is continued for another ten minutes. The hot water in the sink is replaced now with cold and the stirring continues until the bucket contents have cooled to room temperature.

At this point, there should be approximately 790 grams of lead styphnate of the normal type in the bucket. Theoretical yield is 984 grams.

Next, the styphnate must be thoroughly washed. It is a very heavy dense material and settles quickly to the bottom of the bucket. The reaction liquid is poured off and sent to wherever it is all similar industrial wastes should go for purification, lead salts being present.

Using a hose with quite a forceful flow of water, the styphnate is stirred and washed. If necessary, the cake may be broken up using the rubber-gloved hand gently. After settling again, the water is poured off and fresh water added again in the same manner, the wash cycle is repeated four more times.

Now comes a very important point. Before any further handling of the styphnate may be permitted, it *must* be checked for safety. Even with the most care, and with the TNR made as described earlier, an occasional batch of normal styphnate shows up with a chip on its shoulder and must be caught up with and weeded out before somebody gets hurt.

The test is easy. Remember earlier that, in the early days of styphnate development, safety was checked by a spit of flame from a piece of dynamite fuse. Nearly the same test, but more rigorous, is applied.

Take a small thumbnail sized pat of styphnate from the bottom of the bucket. Use a plastic spatula, not a metal one. Place this pat on a sheet of brass and blot with a paper towel, pressing down with the thumb. Apply fresh portions of the towel until the paper comes up apparently dry. Now, immediately cover the dried pat with a thin layer, a gram more or less, of blackpowder. Cut a small 3-4 inch piece of dynamite fuse, split one end, and embed a match head in it. Point the other end of the fuse, using a burette clamp or similar clamp, so that the burn-out from it will spit on the black powder and ignite it. Light the match and the fuse will ignite. When the fuse lights the blackpowder and it burns, the styphnate underneath gets a severe test of its temperament. The reaction may vary all the way from a simple blackening of the styphnate surface to complete detonation. Interpretation of the relative degree of disruption of the pat is the key as to whether to use the material further or not.

If the surface of the pat is only pitted, even heavily pitted, but is still essentially intact, the styphnate is okay to use, but if the pat is broken up and scattered, burns completely or explodes, then it is too touchy to handle and must be scrapped forthwith.

Bear in mind that styphnate to be scrapped is extra dangerous and must be dealt with gently but firmly. Don't dump the bucket. Don't attempt to remove the styphnate from the bucket. Perform the execution on the spot and at once.

Dissolve 300 grams of sodium hydroxide in 5 liters of water. Again, using a forceful stream of water to break up the cake in the bucket, fill the bucket about $\frac{1}{3}$ full of water and place under a stirrer in the water bath. Raise the temperature in the bucket to 50-60°C. Add the NaOH solution, continue stirring for two minutes, then pour in 500 cc of acetic acid, allow to react for a minute or two and sniff the mixture. If the odor of the acetic acid is not present, add a little more until the odor lingers after the addition, or to be more scientific, check to make sure the solution is acid. The contents of the bucket are now a mixture of lead acetate and sodium styphnate plus water. Fill the

bucket the rest of the way with water to dilute the contents, then send the contents on to waste water disposal.

Along this line, all priming buildings must have explosive sumps or catch basins, so that, when scrap priming from tables or washing areas, etc. is washed down, the priming material gets trapped in a convenient spot, where it may be disposed of from time to time. It's very unhealthy to start digging up an abandoned sewer sometime later and have it go bang from dried out collected explosive. Treat the material in the sump with caustic and acetic acid as mentioned above, and wash it away. Use hot water to increase the solubility of the material.

While on the subject, it sometimes is necessary to scrap tetracene for various reasons. Hot caustic solutions will decompose the tetracene, and in so doing, the odor of ammonia will be given off, an indication that decomposition has occurred. Use caustic at the same concentration as for scrapping styphnate.

A few words on safety, now that three explosive products have been made.

First of all, wear safety glasses at all times when working with acids, caustic, explosives and priming mixes.

Second, keep all working areas scrupulously clean. Don't let any styphnic acid, styphnate, tetracene, or priming mix dry out before trying to clean it up. Make sure all explosive gets washed into the sump.

Third, remember that lead salts are poisonous, and sodium nitrate and aminoguanidine are likewise unhealthful. Sodium nitrate, if absorbed by breathing in dust or from the hands, affects heart action. Use a dust respirator and wear rubber gloves when handling styphnate. Wash the hands before eating.

Primer Mixes

Having made or purchased the necessary ingredients, the next step is the actual making of the mix.

Take, for a typical example, Type IV in the earlier list of mixes for small rifle primers:

	1 kg. mix	
PbStyphnate	37%	370 grams
Tetracene	4	40 grams
Barium Nitrate	30	300 grams
Antimony Sulfide	25	250 grams
Aluminum	4	40 grams
PETN	5	50 grams
Gum Solution	–	30 cc

The gum solution in the mix formula requires careful preparation. The formula is as follows:

Gum Tragacanth	100 grams
Gum Arabic	50 grams
Gelatine	10 grams
Thymol	1.5 grams
Water	2.9 liters

The two gums and the gelatine should be added to the water while stirring vigorously. Continue stirring and heat the mixture to 70-75°C, maintaining temperature for three hours. Cool to room temperature. Dissolve the thymol in 15 cc of alcohol and add to the gum solution.

The gums in this solution represent a fine culture medium for wild, unwanted fermentations, hence the thymol as a preservative. Even so, the solution has a short life unless kept refrigerated.

Strain the solution through cheesecloth and store in stoppered bottles. If not used in two weeks, throw away and start over, unless refrigerated.

Two of the ingredients, lead styphnate and tetracene, must, for safety's sake, be kept wet and handled wet until the mix is safely in the primer cup.

The rest of the ingredients may be mixed and handled dry, remembering at the same time that the list contains both fuel and oxidizer, and would burn furiously if set afire by accident or otherwise.

The first problem is how to measure out a given amount of styphnate and tetracene, when both are wet. It is, of course, possible to go the long way around and take a small representative wet sample of each, weight the wet sample, dry it, and compute the percentage of moisture as being the same in the larger amount. This takes time and there is still the small dry sample as a hazard.

Fortunately, there is a better way, made popular by an ancient named Archimedes, who at the same time popularized a household trademark word, when he leaped from his bath, grabbed a towel, and, shouting "Eureka," headed for the lab. He had hit on a plan to weigh the emperor's gold crown in water to see of the royal jeweler had fudged a bit. Sneaking a little of some base metal in with the gold, heaven forbid, would hike up the jeweler's profit.

Likewise, the styphnate is weighed in water and, because the styphnate is so much denser than water, Archimedes' system works quite well, although with gold it's maybe more fun. The density of styphnate is 3.03, while that of water is 1.

One starts with a simple weighing vessel, in this case one with a drip spout to catch the overflow, called a pycnometer. Fill it with water, weigh it, add styphnate, let the displaced water overflow and again weigh the pycnometer. The weight will naturally be increased. The overflow water displaced by the styphnate may also be weighed. If one takes the increase in weight of the pycnometer and adds to it the weight of water displaced, then lo and behold, the weight of the styphnate appears.

For example:

Weight of pycnometer, with styphnate, full	1500 grams
Weight of pycnometer full of water only	1165 grams
Weight difference	335 grams
Weight of water displaced	165 grams
Dry weight of styphnate in pycnometer	500 grams

It isn't necessary, however, to catch the water displaced and weigh it. Remember that the density of lead styphnate is 3.03. Then a weight of 500-gram of styphnate would occupy a volume equal to 500 divided by 3.03 or 165 cc. A volume of 165 cc of water weights 165 grams, which is what the styphnate displaced, as we saw above. This is 33% of the total weight, meaning that the weight difference was 100% minus 33%, or 67% of the total 500 grams weight of styphnate we determined was in the pycnometer. This 67%factor is common to any weighing of styphnate regardless of the size of the pycnometer or the amount of styphnate weighed.

To get the weight of styphnate simply divide the weight difference between pycnometer with styphnate and pycnometer with water only by .67. $335 \div .67 = 500$.

With tetracene, whose density is only 1.63, accuracy is not quite as good, but a little further refinement in method as shown below gives very satisfactory results.

Weight of pycnometer with tetracene, full	1500 grams
Weight of pycnometer full of water only	1307 grams
Weight difference	193 grams
Weight of water displaced	307 grams
Dry weight of tetracene in pycnometer	500 grams

Again, the volume of water displaced is the same as the volume of tetracene added, 307 cc, and this is $307 \div 500$ or 61.4% of the total weight of the tetracene. The difference weight of 193 grams is then $100 - 61.4$ or 38.6% of the total weight. This 38.6 factor is also common to all weighings of tetracene, regardless of the amount of tetracene or size of the pycnometer.

The rule in applying either of these factors, 67% for styphnate, 38.6% for tetracene, is that the *weight difference* to be sought in adding the material to the pycnometer is 67% of the dry weight desired in the case of styphnate, and 38.6% in the case of tetracene.

Tetracene, being light and finely divided, stays suspended in water, when stirred, for an appreciable time. It is thus possible to suspend the 500 grams weighed out above in two liters of water, and then draw off a 50 cc sample, filter out the tetrazene on a weighed filter paper, dry the material on the paper, reweigh, find the weight difference and compute the actual concentration in the larger quantity, to check on the accuracy of the original weighing. In making up the primer mix, a volume of the slurry containing the appropriate amount of tetracene may then be drawn off to be mixed with the wet styphnate.

Again, a note on safety. Lead styphnate, being heavy, tends to pack solidly in the bottom of a container. When transferring styphnate to the pycnometer, don't dig it out with a spoon, spatula or other handy digging instrument. In order to avoid any chance of an unpleasant incident, use a stream of water to break up the cake, swirl it about and pour the slurry into the pycnometer. The excess water will run off as it is supposed to and the styphnate will settle out. If, by chance, too much styphnate is poured into the pycnometer, use the gloved fingers to pick the excess out, or swirl it out into the original container. Most pycnometers for this purpose are made of stainless steel, and styphnate must not be left in them overnight, because of the danger posed by the sensitive crust, that shows up as a small fringe at the upper surface of the liquid where it meets the metal.

At this point, the two wet explosives are mixed together, again under water. The proper amount of tetracene slurry, as determined earlier, is poured into the styphnate container and, with water plus the rubber-gloved hand, the two are mixed thoroughly together, and the excess water poured off.

The dry mix is made by weighing out the proper amounts of the balance of ingredients, except PETN, in the formula. All lumps must be broken up and the mixing must be thorough before adding the wet mix.

At this point, the gum solution is added to the dry mix and kneaded in, followed by the PETN, which should be dampened to prevent dusting.

Next comes the styphnate-tetracene wet mix. Initially, any excess water on top of the mix is poured off, but it must be remembered that the final moisture content in the complete mix should be about 15%. This means that the total amount of water in the mix will be about 150 cc. At this moisture, the mix should be a little like very damp sand. As the mixing proceeds, a little water is added from time to time, if the mixture seems too dry.

For small mixes, hand kneading with rubber gloves is satisfactory, if time consuming. For larger mixes, a mechanical mixer is a real necessity. It should be of stainless steel, with mixing blades that conform closely to the inside of the mixer, but with uniform safe clearance between the blades and mixer. Even with a mixer, mixing time should be about 20 minutes; double that is needed with

hand mixing. With a mechanical mixer, all the dry ingredients are put in first, followed by the gum, PETN and the wet styphnate-tetracene mix.

After dumping the mix, the mixer must be thoroughly washed down to remove all traces of mix. A bit of dry mix from an earlier batch could explode with the first movement of the mixer on a new batch with disastrous results.

The mix is now ready for use. It should be kept stored in tightly covered plastic or rubber containers to prevent dangerous drying out. Storage should be in a cool place or under refrigeration (not frozen). Warm storage may give problems with the gum deteriorating.

If, by chance, there is too much moisture in the mix, it may be dried out to the proper moisture by exposure to a warm air current while turning the mix over with the gloved hands.

With a moisture content at 10% or above, the mix is not ordinarily violently explosive. The initiator has been dispersed in the other ingredients, and the water desensitizes it very efficiently. Even so, the mix should be treated with deference, and incendiary influences are to be avoided.

When handling priming or primers, anything less than absolute attention is taboo. Wool gathering, pious contemplation of the navel, girl watching, idle conversation and carelessness are included in the ban. Indeed, any individual given to any of the above, even on a warm spring day, has absolutely no place in the primer line. Nor is there a place for the tendency to panic or lose self-control.

Something entirely new in priming, called Eleyprime, has recently been developed by Eley Cartridge. The process is an long stride forward in safety, has been fully tested, and is available for license.

While the exact process is known to the author, it was only disclosed by Eley after receiving a vow of secrecy, and cannot be fully covered here. The broad principles have however been published.

Eley prepares a special "Premix" of completely dry chemicals which burn but do not explode under normal conditions. The rate of burning is slower than that of shotgun propellants, for instance, when the material is laid out in a train and ignited.

The Premix composition for rimfire is different from that used for centerfire primers.

Either mix is placed in the proper shell or cup in the dry state, then wet with a small amount of water. Upon drying the mix is activated to full sensitivity and performance equal to that of conventional primers. I have tried the method on a small experimental scale, and it works.

The big advantage of the process is in the inherent safety involved. The special precautions for making and mixing lead styphnate, for example, are not needed. The amount of barricading required is small, reducing the initial cost of a priming operation. In the actual priming of shells and caps, no special protection for the operator is needed.

Equipment for the Eleyprime system has been developed jointly by Eley and Lachaussée.

Those who are already using the wet priming process may choose to continue present methods because of the cost of licensing. Any new manufacturer should give serious consideration to the Eleyprime method.

This is not a paid advertisement, by the way, but a simple note on what's new in the business.

Cups and Anvils

With the priming mix made, metal parts come next. Centerfire cup and anvil are both made from 70/30 cartridge brass. The cup is frequently nickel plated, mostly for identification or cosmetic purposes.

Plating to prevent mercury from working on the brass in the cup is not necessary since mercury fulminate is no longer used in priming mixes.

Plating does make a better looking primer and stays shiny, where brass would tarnish.

Dimensional control of cup diameter, inside and out, must be carefully maintained. Likewise diameter, height, and shape of anvil are critical.

The primer cup must fit the primer pocket in a cartridge case tightly, so that hot gas doesn't leak around the primer, but not so tightly that the primer becomes deformed during seating in the pocket.

Anvil diameter and cup inner diameter have to be kept together, so that the anvil can be seated accurately during assembly, but doesn't fall out during normal handling and loading.

Cup height and anvil height go together. The cup must be low enough to fit below flush in the case pocket, yet still high enough to hold the anvil in place. The anvil must seat so that part of the legs show above the cup rim; at the same time, a proper space between anvil tip and cup bottom must be kept.

Anvil shape is important in providing a point against which the mixture is squeezed by the dented cup under th firing pin blow. If too blunt, there is too much cushioning of the blow and insensitivity results. Too sharp, and the bad effect of a slightly off center blow increases.

Table 5 shows diameter and height relationships and tolerances of anvils and cups.

In order to keep control of cup height, the thickness of the metal strip from which the cup blank is punched must be held to close tolerances. Metal thickness specifications are as follows:

Small pistol	.0173 – .0178"
Small rifle	.0205 – .0210" - Commercial
Small rifle	.0240 – .0245" - Military
Large pistol	.0205 – .0210"

Large rifle	.0265 – .0270″
Anvil, all	.034 – .035″

It is reasonable to have two sets of blanking dies and punches on hand. One makes a slightly larger diameter blank to be used when the metal strip is running on the thin side. The other set makes a smaller blank when metal is on the thick side of tolerances.

These two dies produce cups of fairly standard height. The thicker brass strip would make a longer cup if the larger blank is used. The reverse would happen with the thinner brass and smaller cup.

Blank diameter for a small rifle primer cup, using brass of .0240″ thickness, would be about .2433″. Brass of .0246″-thickness would need a blank of only .2408″ diam. to make a cup of the same height.

Shotshell primers have a third component. This is the "battery" cup, which holds anvil and primer cup in position. The battery cup can be made of either brass or steel. Steel, if used, is either copper or brass plated, either before or after forming.

A newer type battery cup, produced by Lachaussée of Belgium, is a combined cup and anvil, cleverly drawn from steel strip. While the tooling for this cup is complicated, the cup with anvil has definite advantages in making primer assembly easier.

For many years American shotshell primers used one of two different battery cup diameters. Remington's 157 has a body diameter of .229″, while the 209 of Winchester-Western, CCI and Federal is .240″. Recently, though, the "209" size seems to have won out. Remington's 1988 catalog lists only 209-size shotshell primers in the section on reloading components. Internal dimensions are up to the manufacturer.

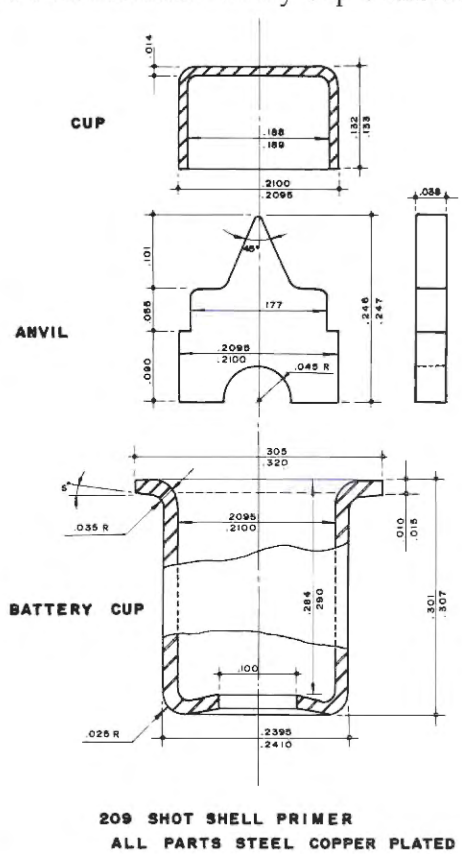


Figure 40: Components and Dimensions for 209-Size Shotshell Primer

Battery cup dimensions are as per the sketch shown in *Figure 40*.

Anvil for primers are of several different types, shown in *Figure 41*.

The two-legged anvil (1) is easier to make tooling for. Any mismatch between large anvil diameter and small cup diameter tends to make an oval primer which is not very good for assembly.

Style 2 is the most popular Boxer type and it makes a good round primer.

Style 3 is the CIL type. The four flash holes are hard on the tiny punches. The anvil, though, is still usable, even if one or two of the flash holes are missing, but not if three of the punches break.

No. 4, the "Berdan" primer, has the anvil integral with the case pocket. Flash holes must be drilled through the bottom of the pocket at an angle. Reloading is more difficult as the fired primer cannot be punched out as the Boxer type can. Primer production is certainly simpler. The cup only has to be charged, foiled and lacquered.

The old standard shotshell primer anvil, shown in 5, is stamped out of sheet brass. Unless width is carefully held, the anvil may tip sideways at assembly. With the anvil tip off-center, misfires may occur.

A newer type shotshell anvil appears as No. 6. Needs a double-action press fed with copper plated steel strip to form. Is easy to load and centers well in battery cup. Tooling is more complicated than 5. Probably the best choice.

A cup such as in *Figure 42, a.*, makes anvil seating easier. There is a smaller area at the top of the cup to hold the legs of the anvil, so it is more liable to fall out.

The top of the primer cup must be controlled as to shape. A cup top like that shown in Fig. 42, b. makes it difficult to seat anvils. It does go in the primer pocket easier, but the primer manufacturer can't afford the assembly problems.

Even-top cups, or those slightly dished as in *Figure 42, c.* are the best compromise.

Cup top shape is controlled by clearance between blanking punch and blanking die and by die radius. Greater clearance leads to example one above.

Figures 43 and 44 show the essential tool dimensions for a large rifle primer, using strip .0265″ – .0270″ thick, and a small pistol primer using strip .0173″ – .0178″ thick.

Tooling should be of steel or carbide for the die; chrome-plated steel for the punch.

Anvil profile and height can be altered by in-

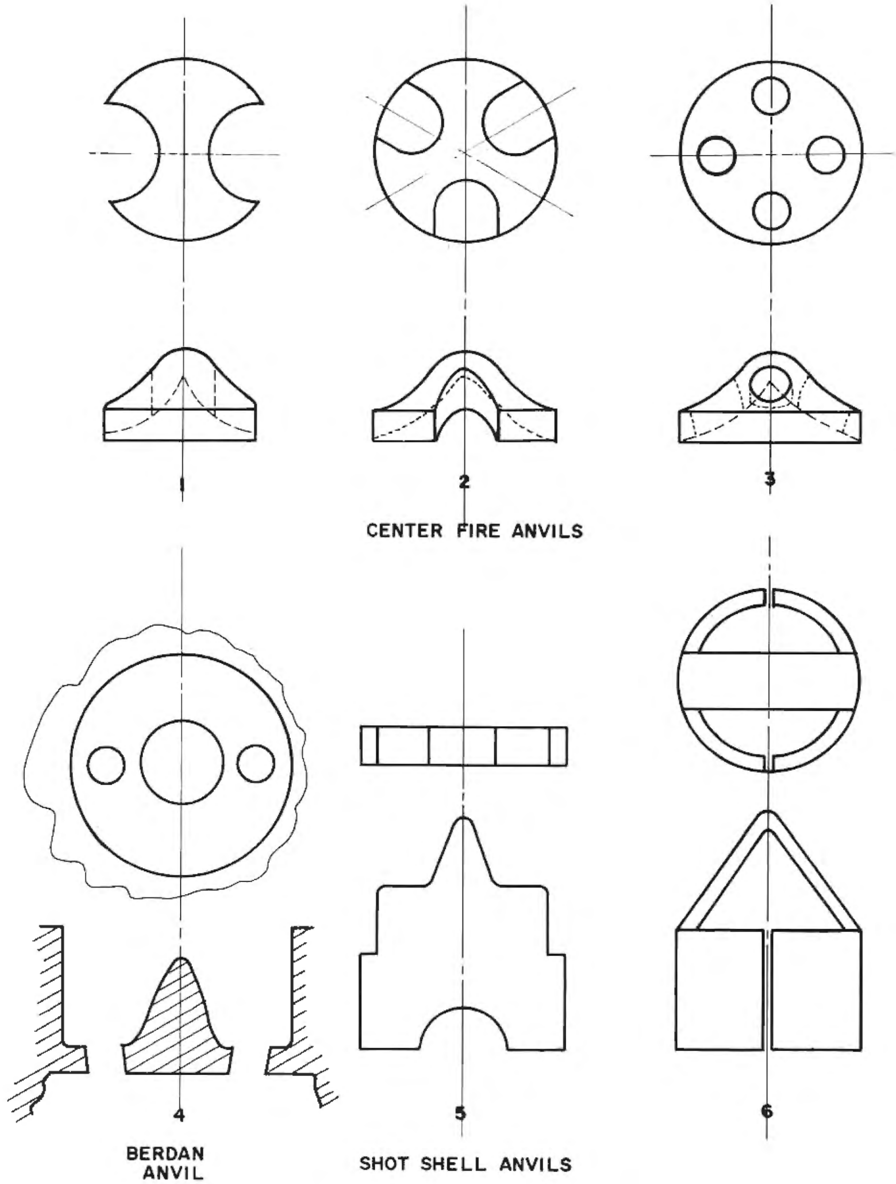


Figure 41: Primer Anvil Shapes

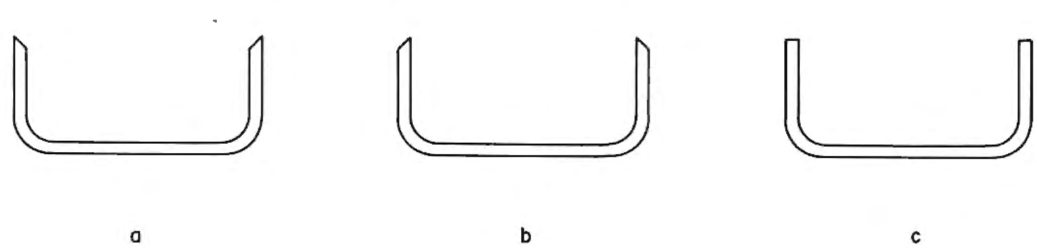
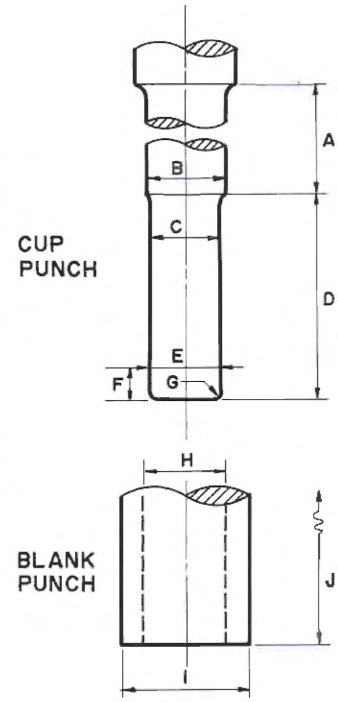


Figure 42: Primer Cup Shapes

PRIMER CUP

SIZE	LARGE RIFLE	SMALL RIFLE
METAL THICK.	.0265-.0270	.0240-.0245
A	OPTIONAL WITH J	
B	.199-.200	.1556-.1558
C	.1834-.1836	.1456-.1458
D	1/2	3/4
E	.1833-.1835	.1440-.1442
F	3/32	3/32
G	.005 R	.012 R
H	.200-.201	.1560-.1564
I	.2766-.2768	.2480-.2485
J	OPTIONAL WITH A	
K	.105-.115	.095-.110
L	.240	.240
M	.2770-.2775	.2480-.2485
N	.039	.039
P	.2105-.2107	.1743-.1746
Q	1/64	1/64
R	.090-.095	.025 R
S	.250	NONE
T	.035	NONE
V	.2100-.2102	NONE
CUP HEIGHT	.115-.123	.100-.115



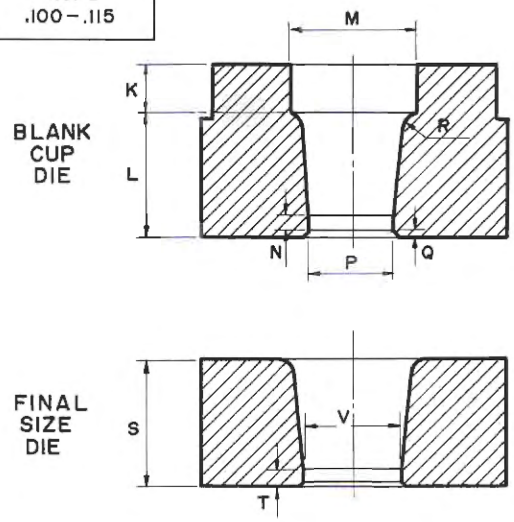


Figure 43: Essential Tooling and Dimensions for Rifle Primers

creasing or reducing the sharpness of the punch point. It is easiest to check anvil shape with an appropriate comparator plate carrying the ideal shape with permissible variations thereto.

Essential anvil tooling dimensions are shown in *Figure 45*.

Centerfire anvils are usually made on a single action punch press with a precise step feed. A good die set, holding both punches and dies in alignment is necessary.

Precise feeding is required to get maximum utilization of the metal strip, with a minimum of defective or mutilated anvils.

If multiple anvils are made at each stroke, the product of each punch *must* be kept separate until checked and found okay to mix with the rest.

Table 5

Centerfire Primer Part Dimensions (in inches)

Primer Type	Cup Outside Diam.	Cup Inside Diam.	Cup Height	Anvil Outside Diam.	Anvil Height
Small Pistol	.1748	.1494	.108	.150	.085
	.1753	.1500	.115	.151	.088
Small Rifle	.1745	.1505*	.110	.1510*	.085
	.1750	.1510	.115	.1515	.089
Large Pistol	.2105	.1830	.110	.1695	.086
	.2110	.1835	.115	.1705	.090
Large Rifle	.2103	.1827	.115	.1836	.083
	.2108	.1832	.123	.1842	.086

* These differ from the dimensions shown in Figures 43 & 45, where thicker metal (.024") is used for the cup. The smaller inside diameter lessens side wall ironing, resulting in more uniform cup height.

Assembly

Once the components are made, a very important step follows. Anvils and cups must be very thoroughly washed to pristine cleanliness. The least amount of soap left will "kill" the primer. The priming mix, in drying, sticks best to a clean, slightly etched surface. This washing procedure indicates how fussy one has to be:

With the anvils or cups in the rotating wash tub (tumbler):

1. Rinse with hot water for two to three minutes.
2. Add 2 oz. of trisodium phosphate or sodium metasilicate per gallon of water in the tumbler.
3. Rinse with cold water, running for five minutes.
4. Add 2 oz. sodium cyanide solution per gallon of water.
5. Tumble and rinse for five minutes.
6. Add 1 oz. sulfuric acid per gallon of water.
7. Rinse with cold water for three minutes.
8. Add 2 oz. of chromic acid solution per gallon of water.
9. Rinse with cold water for five minutes.
10. Drain and tumble.
11. Transfer to dryer and dry.

Sodium cyanide solution is ½ lb. of NaCN per gal. of water.

Chromic acid solution is 8 oz. chromic acid per gal. of water.

Cups and anvils should be stored fully dry and covered. If any tarnish appears during storage before use, the components must be rewashed.

Loading

Loading is next on the list. No attempt will be made to cover dry mix loading. It is too hazardous, takes too much explosion-proof construction, unless one likes to live dangerously. Wet mix loading is the most popular in the U.S. and is beginning to be so in Europe.

Centerfire Primers

1. Centerfire primer assembly begins with operator #1 filling the reservoir in the bottom of the shaker with cups. A cup plate is then placed in position in the shaker. A couple of handfuls of cups are dumped on the plate. The cups fall open end up. Cup plates usually have several hundred holes, 500 being a convenient number.

2. After inspection for foreign matter in cups, and defective cups, the filled plate goes to the charger, who places it under the pin plate.

3. The charger fills each hole in the charge plate with primer mix. He then places the charge plate over the cup plate and drops the pin plate. This forces the primer pellet out of the charge plate and drops it in the cup. The charged cup plate is inspected 100% by the charger for missing, small, or improperly placed pellets.

4. The next step is pressing and foiling. The operator places the cup plate on the foil press. The plate feeds through the press, one row at a time. The foiling punch comes down through the foiling paper, cutting out a disc. Disc and punch continue down to enter the charged cup. The pellet is pressed

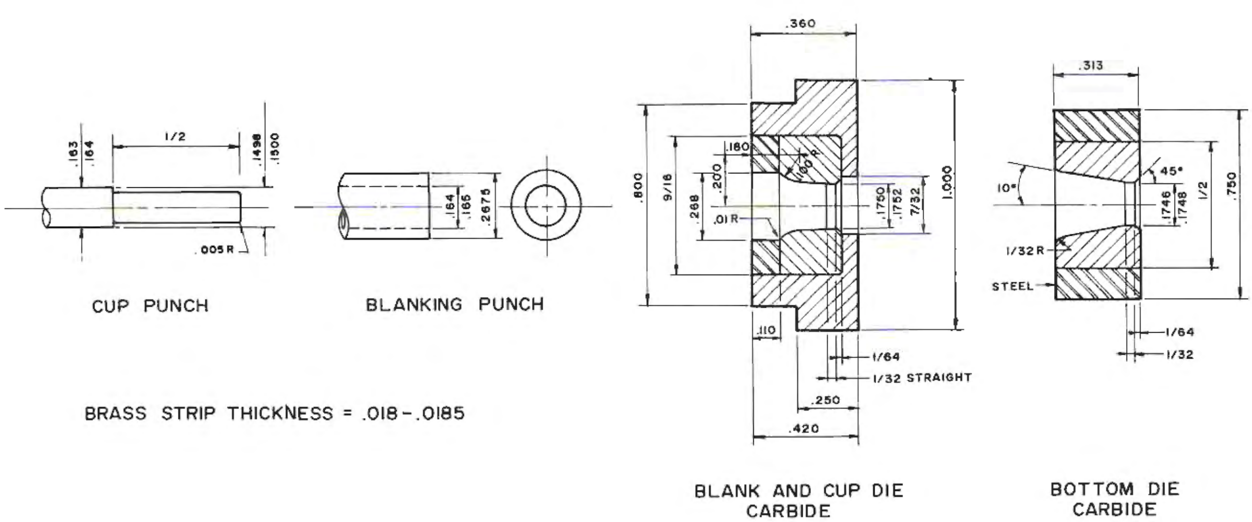
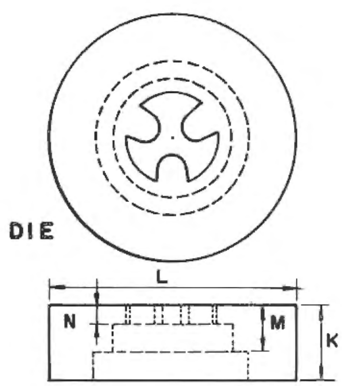
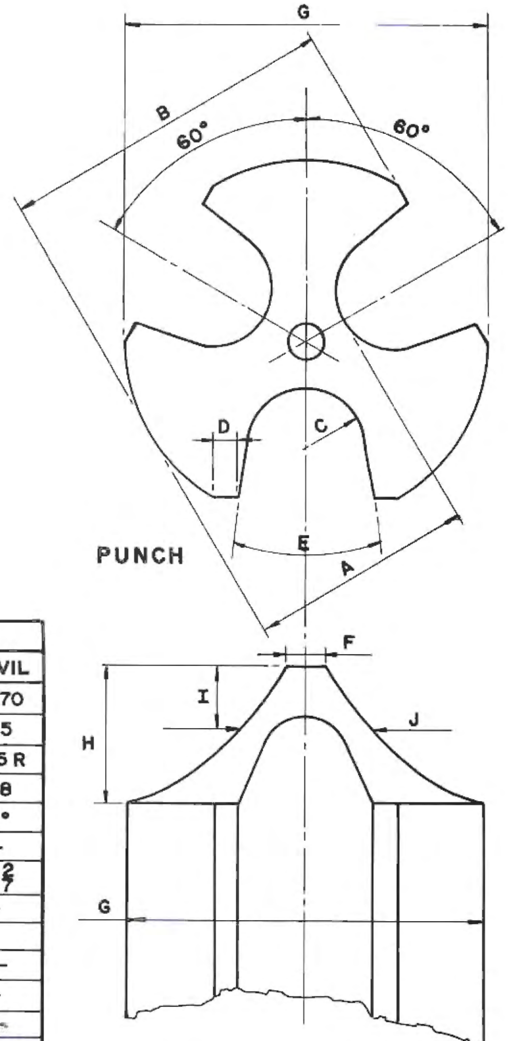


Figure 44: Blank and Cup Tooling for Small Pistol Primer





ANVIL DIMENSIONS

	LARGE RIFLE			SMALL RIFLE		
DIM.	PUNCH	DIE	ANVIL	PUNCH	DIE	ANVIL
A	.1140-.1145	.116	.1155-.1160	.096	.0975	0.970
B	.169-.170	.171	.1705-.1710	.133-.134	.135-.136	.1355
C	.03 R	.03 R	.03 R	.025 R	.025 R	.025 R
D	.012	.012	.010	.009	.009	.008
E	14°	14°	14°	15°	15°	15°
F	0175	—	—	.015	—	—
G	.1815	.1828	.1835-.1840	.1430	.1436	.1442-.1447
H	.068	—	—	.068	—	—
I	.03	—	—	.03	—	—
J	.061	—	—	—	—	—
K	—	.038	—	—	.038	—
L	—	5/8	—	—	5/8	—
M	—	3/16	—	—	3/16	—
N	—	1/16	—	—	1/16	—

METAL THICKNESS .034-.036 — — .034-.036
HEIGHT, OVERALL .086-.090 — — .085-.088

Figure 45: Anvil Tool Dimensions

into the bottom of the cup, and, as the punch rises, the foil paper is left against the pressed pellet.

Foil paper, usually white kraft, is coated with a 5% shellac in alcohol solution and allowed to dry before use.

After foiling, the foiled cups, still in the original plate, go to anvil assembly. On the way, the cups are inspected for missing or crooked foil paper.

5. The anvil shaker, like the cup shaker, has its reservoir filled with anvils. These are dumped, a double handful at a time, on the shaker plate, where they fall pointed end down. After inspection, the shaker plate is booked to the anvil plate and the two plates turned so that the anvils fall into position atop the anvil pins.

6. The shaker plate goes back on the shaker, and the anvil plate and cup plate are booked, taking care that neither cups nor anvils fall out of place.

The two plates, held firmly together, then go on the anvil seating press, cup plate on the bottom.

7. Advancing through the anvil press, the assembly pins push the anvils into the cups, one row of 10 anvils, at a time.

Coming off the seating press, the anvil plate is lifted off.

8. The anvilled cups, in their plate, then go to the lacquering unit. Before inserting the plate, the lacquering pins, one for each primer, are lowered into the lacquer tray, collecting a drop of lacquer on each pin.

9. The cup plate is then inserted into the unit, and the plate of lacquer pins lowered to deposit their drops of lacquer, one on each primer. This seals surface of primer mixture and foil paper.

The lacquer used is a nitrocellulose type. A formula:

.5 kg.	30-40 Second Nitrocellulose

96. kg.	N.Butyl Acetate
23.6 kg.	Ethyl Acetate
1.3 kg.	Denatured alcohol (Methanol)
.15 oz.	Red Spirit Dye

The dye should be dissolved in .7 kg. of a 4 to 1 methanol-n.butyl acetate mix and added to the lacquer.

10. After removal from the lacquer unit, the plate of loaded primers is carefully inspected for missing, tipped, or deformed anvils. Loose anvils are caught by lightly scraping the primers in the plate. All defective primers are picked out and dropped into water for scrapping. *Figure 46* shows the various steps.

Four operators and one inspector can load about 200,000 primers in one 8-hour shift.

Rimfire Priming

Rimfire primer loading is simpler than centerfire, there being only cases and mix to handle, and only a shaker and plate, a charge plate, a pin plate and a spinner needed.

The steps are these:

1. The shaker operator fills the bottom of the shaker with empty cases, and starts the shaker with a shaker plate in place.

2. Next, several handfuls of cases are dumped on the shaker plate and, Under shaker motion, the cases drop into the plate holes, mostly head down. The operator reverses the few that dared to be different.

3. Taking the plate of cases from the shaker, the operator inspects for damaged case mouths, short

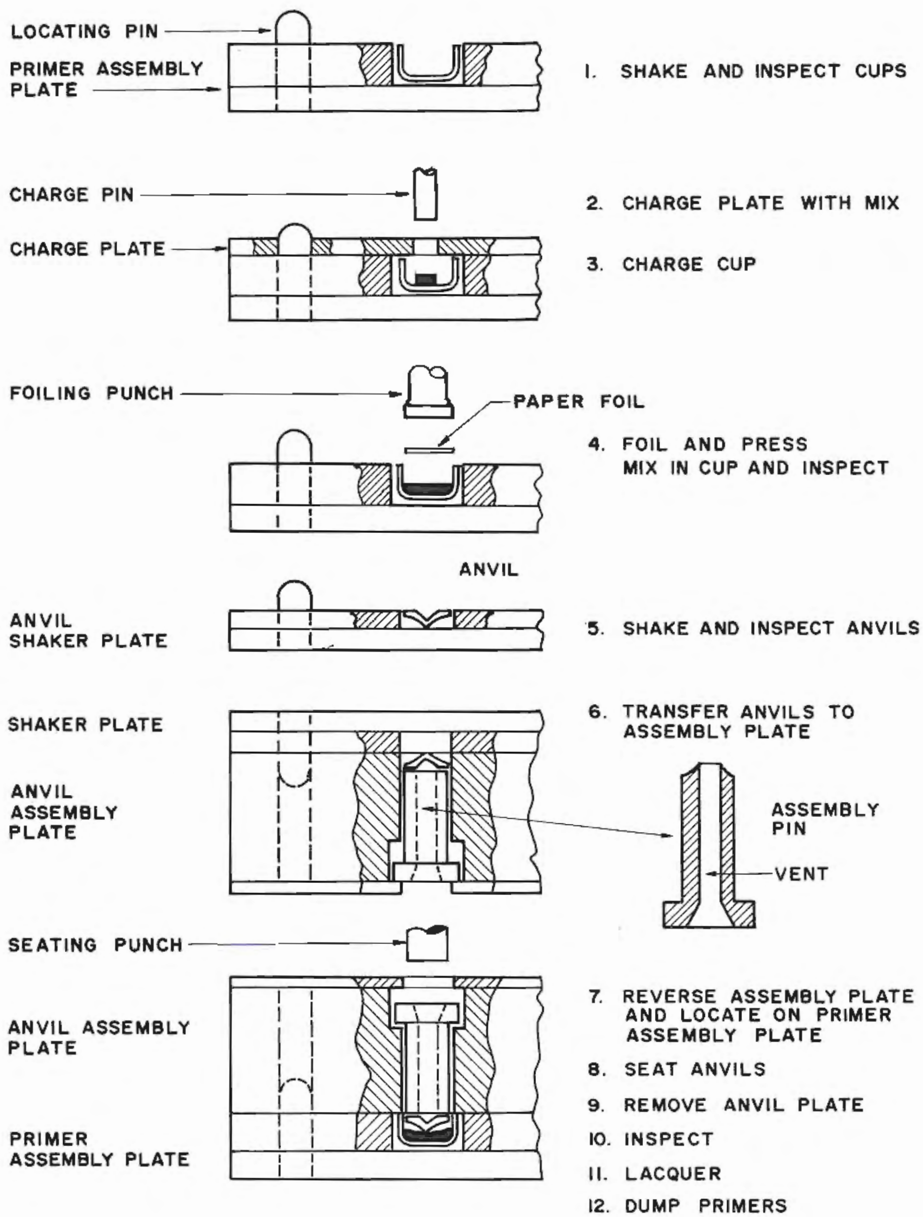


Figure 46: Primer Loading Steps

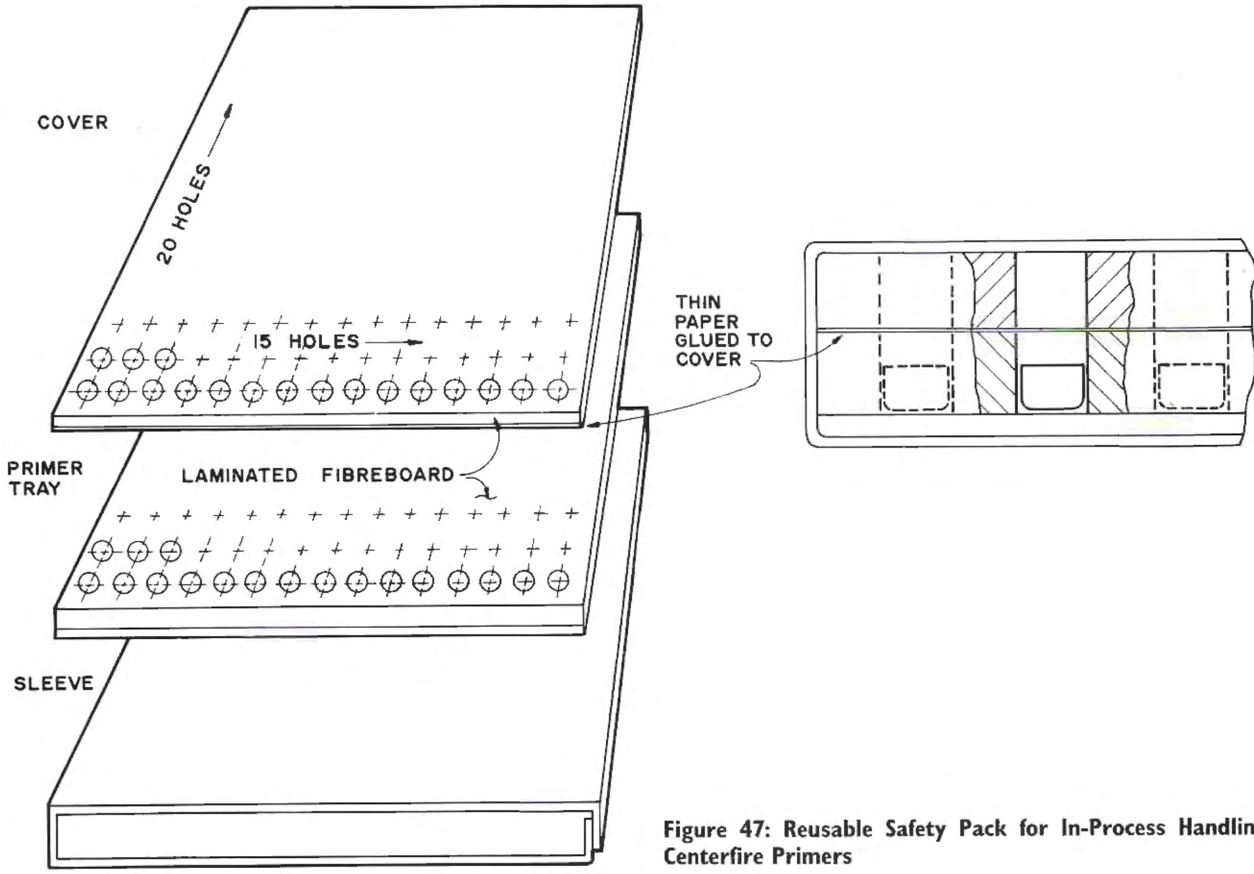


Figure 47: Reusable Safety Pack for In-Process Handling of Centerfire Primers

or long cases, or those that might have gotten some foreign material inside. There are 500 to 1,000 cases in the plate. Inspection might seem to be tedious, but it isn't. With 499 out of 500 looking alike, the oddball sticks out like a good deed in a naughty world. Apologies to Shakespeare. Holes in the shaker plate are a bit sloppy to make it easier for the cases to drop in place.

4. Next, the operator fits another more precise plate on top the charge plate, putting the two together like closing a book, and flops the two plates over, dropping the cases—mouth down—into the second plate. The shaker plate then goes back to the shaker. On the second plate, by sliding a thin cover plate into grooves, the case heads are covered, and turning the second plate over, the cases will be mouth up, closely aligned, for charging.

5. In the meantime, the charger has placed the charge plate on the charge table and has rubbed the priming charge over it so that each hole, corresponding to one case plate hole, is completely filled with wet priming mix.

6. The charger then positions a plate of cases under the pin plate, and places the charge plate on top of the case plate. Dropping the pin plate forces the pellets of priming out of the charge plate and drops them into the bottoms of the cases (See Figures 47 & 48).

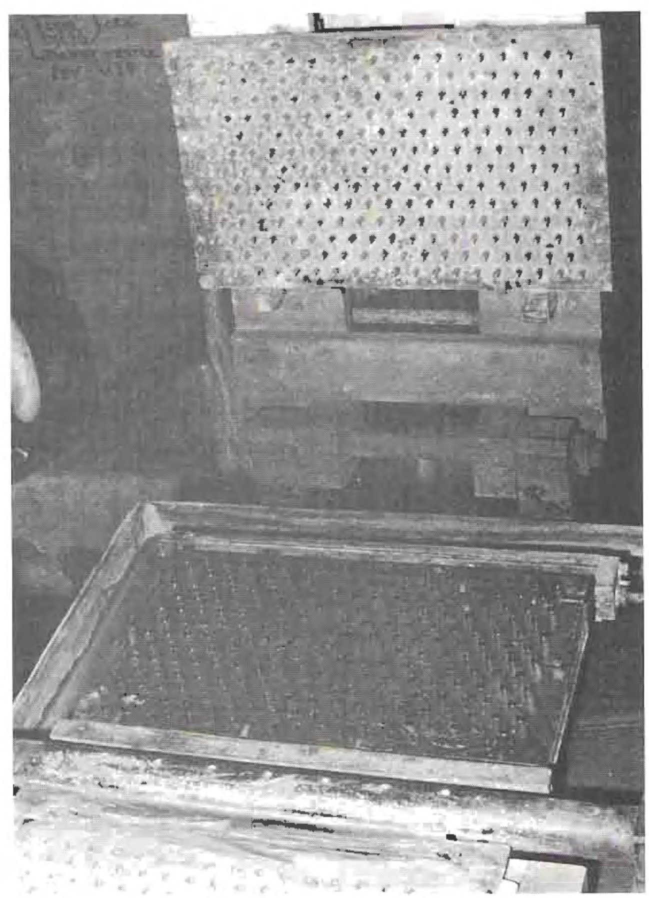


Figure 48: Rimfire Priming Charger

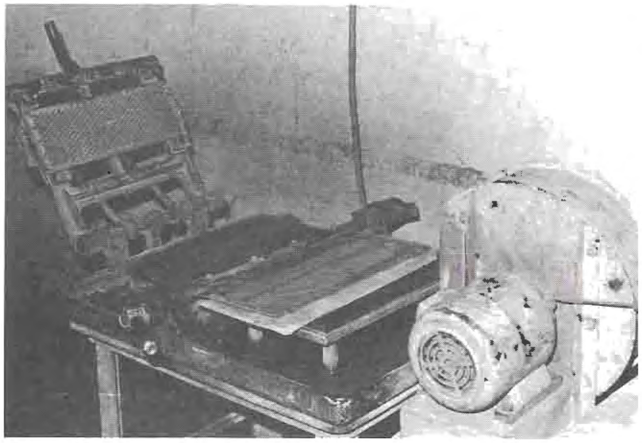


Figure 49: Rimfire Priming Inspection

7. The charged cases are then passed to the spinner operator, who inspects for missing pellets and then places the plate of cases on the spinner table, pulls out the thin bottom plate, then lifts the case plate up. This leaves the 500 cases standing upright on the spinner table. They are then fed to the positioning dial on the spinner (See Fig. 49). The feed picks one case at a time and positions it under the spinner bit. The spinner, rotating at 3500 to 4000 rpm, lowers the spinner bit to the bottom of the case. The bit spins the pellet of mix firmly into the rim cavity (See Figures 50 & 51).

Humidity should be kept at a 70% level or higher in the priming area. If there is a delay of several minutes between dropping the pellet and spinning it, the priming may fire when the spinner hits it.

This was a problem in Mexico. At the 6000'-plus altitude of San Luis Potosi, the humidity was frequently below 10%. If the spinning machine was stopped for more than two minutes, almost every case would pop when spun. To cure this situation, humidifiers sprayed water into the air continuously. Outside in the sunlight, charged and spun cases would be completely dry in less than an hour.

Adding more water to the mix is no cure for low humidity. Charging is less uniform and spinning

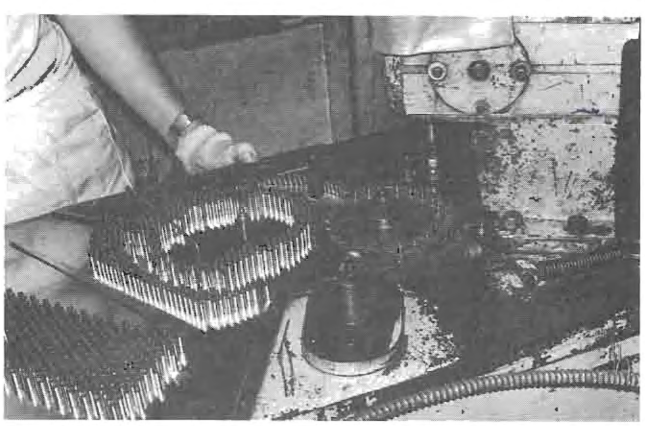


Figure 50: Rimfire Priming Spinning

is uneven. Moisture control in the mix is critical; no more than is necessary for even charging and spinning is permitted.

8. The primed cases then go to the drier. After drying and drop testing a sample for sensitivity, the cases are ready for loading.

One priming unit of the type described can produce up to 250,000 shells with three operators and one inspector per shift. On a lesser scale, one operator and one charger can do 100,000-plus, per shift.

Quality Control is in these steps:

1. The mix is pre-tested for sensitivity before being released for charging. A sample of cases is charged, dried and drop tested, 25 at 7" with a 4 oz. ball. No misfires are permitted. See Chapter IX for primer sensitivity testing.

2. Dimensional control of cases has been maintained during production. control charts are usually kept on trimmed shell length, head diameter, rim thickness, and headed length. Sidewall thickness on drawn cases is kept to a maximum variation of .0015", with .001" being the usual.

Figure 51: Rimfire Priming Spinner Bit

3. As noted above, before charging, the shaker operator or an inspector checks each plate of cases.

4. After charging, but before spinning, each plate of charged cases is checked for the presence of a priming pellet.

5. Frequent inspection is made of individual spun cases. In addition, the spinner bit is changed at regular intervals, depending on the wear characteristics of the average bit. After a specified number of cases has been spun, the bit is changed regardless of its condition.

6. Dried cases are sampled and 25 rounds from each hour's charging are drop tested at 6", 4 oz. ball. One misfire is permitted at 6" if a retest at 7" produces no misfires.

7. Control charts are kept on primer pellet weight. Average should run between 0.27 and 0.31 grs. Samples of 10 are checked every hour. Maximum individual pellet weight is .35 grs., minimum us .23 grs. If these limits are exceeded, the work is held up for recheck. Verification of excesses requires that the hour's production be scrapped. An upper limit of .40- and a lower of .22 grs. are the governing factors.

Primer Packaging

The finished primers, still wet, are then dumped on the packing table, where they are shaken into packing trays of 100 primers each.

Packed primers then go to the drier, after which the trays are inserted in their packing sleeves. The last step is to pack 10 trays into the 1000-pack box, then into the final packing case.

Primers are packed into their final trays while still wet, in the interest of safety. Bulk primers must never be handled dry. They are subject to mass detonation. A thousand, or fewer, dry primers can severely injure or kill the person handling them. It goes without saying that all priming operations require the wearing of safety glasses at all times on the job.

A special safety pack for handling in-factory production primers was developed by Al Hill and others at Winchester. There had been occasions when dry primers being handled loosely in small boxes had exploded. There was exposure of the priming machine operator in charging primer reservoirs for the machine. Even though operator worked behind a barricade, with only the hands exposed to the primers, there was danger. Primers had to be dumped on a plate, oriented right side up, and transferred to the reservoir.

The newer system eliminated any handling of dry primers, except for the final transfer to the reservoir. At the time of primer loading, the wet primers were shaken into a heavy fiberboard tray, one primer, anvil up, to each hole in the tray. Holes were spaced about one primer diameter apart. The tray with its primers went through a bell dryer under infra red lamps.

On the far side of the dryer a thick funnel card, with holes corresponding to those in the primer tray, was added. The funnel card was entirely covered on its lower side with a sheet of thin paper. Primer tray and funnel together were slid into a stout cardboard sleeve, which held them tightly together. The pack was then ready for transfer to the case priming area.

The idea of the pack, beyond the safety aspect of packing wet primers, was to prevent possible mass explosion of a whole tray of 1,000 primers. A single primer exploding would blow a hole in the thin paper of the funnel card. The flame and hot gases would then expand over the upper surface of the funnel card. The paper cover of the funnel card would prevent flame from setting off other primers.

In use the pack permitted the primers, a trayful at a time, to be loaded directly onto the metal tray of the priming machine reservoir without further handling. The entire pack was re-usable (See Fig. 47).

Control of Primer Quality

Special emphasis is to be placed on control of dimensions, pellet weights, and sensitivities. The following are musts:

1. Dimensional control of cup height and diameter, using control charts, posted at least twice daily.

2. Dimensional control of anvil diameters, height and shape. Ring gauges for diameter, snap gauges for height, or better yet, a comparator plate for height and shape.

3. The priming mix is pre-tested for sensitivity in primer components of established quality before release to loading

4. Control charts are kept on pellet weights. Samples of 10 are checked every hour. For small-sized primers, dry pellet weights for the sample should average between .325- and .425 gr. For large-sized primers, the average weight of a 10-primer sample should fall between .55- and .65 gr. Samples are taken from unpressed primer cups and dried for 30 minutes at 150-160°F

5. Inspections during loading were mentioned earlier.

6. Hourly samples of primers are taken for drop testing.

CHAPTER VII
POWDERS

After I'd finished my work at Western Cartridge on the dynamite filler problem and had put in considerable time in the Cellulose Research Corporation, a subsidiary division, working on the refining of wood pulp for nitration and acetylation, and after a stint in the experimental priming lab, I was moved to Western's smokeless powder engineering department.

The engineering office was located about the middle of the powder mill area amid a collection of somewhat odd looking and specially constructed buildings characteristic of the requirements of a blackpowder production line—which is how the powder mill began. Blackpowder had long since ceased to be manufactured by the company, but the old buildings were still there and in good condition.

Many of the blackpowder people were still in the powder mill working on smokeless powder. There were two noteworthy Smiths among them, one of whom, known as Powder Mill Smitty, was the plant foreman. There were so many foremen named Smith in the plant that they were called by their department names. There was Shot Tower, Shotshell, Powder Mill, and, in the detonator department, Fulminate Smith.

Powder Mill Smitty was a dedicated cigar smoker, but no smoking was allowed inside the gate. There was also a strict prohibition against matches or lighters of any kind in the plant. In the wooden gatepost at the entrance to the plant a small square niche had been cut for Smitty's cigar, which he snuffed out before entering the plant. At lunchtime, when he came to the gate, the cigar came out and was consumed the rest of the way. Periodically, someone would carefully draw a horse hair through the center of the cigar. When Smitty returned and lit up, the language was hot enough to have started a fire inside the plant without a match.

One day the gate was bumped by a truck and the gatepost fell. As soon as the new post was in, a millwright, chisel and hammer in hand, created a new home for the daily butt.

The other Smith was known as "Hytelya," (emphasis on the "haitch,") his real name appearing only on his time card. The "Hytelya" came from his normal way of beginning every conversation. His job was to tend the powder driers. This was the most hazardous job in the plant, and few envied Hytelya's position. But no one could fault his safety record. He'd already survived many years on the blackpowder line where fatal accidents were more apt to happen than on the smokeless line.

The company, then, was making most of its own powder for its shotshell loads and most of its rimfire loads, starting with cannon powder. This powder had been produced during World War I and had been declared obsolete and overage. It made a good starting material for commercial use, however, as the further processing took care of any deterioration in the large grain and further stabilized the powder. This powder predated Ball powder, which came later, but which started from the same raw material.

About 30 million pounds of this cannon powder were stored in the plant in large wooden tanks under water. The powder was removed from the tanks, ground with running water on a hammer mill, placed in a jacketed kettle and treated with ethyl acetate in water to soften the surface of the small particles, which then stuck together as agglomerated larger grains. The agglomerate was treated with a certain amount of nitroglycerin to increase its potential or energy. Then another material, locally known as "Doodle Bug Pee," actually di-butylphthalate, was added as a deterrent to control burning rate, coating the surface of the grains.

My job at the time I went to the Powder Mill Engineering Department was to design all of the new buildings and equipment, and equipment layout, to double the Powder Mill's capacity to produce its agglomerated powders.

Concurrently, another group led by Ernie Silk was working on the development of Ball powder, which was, to a degree, a fairly natural follow-on from the agglomerated idea.

The ground cannon powder was dissolved in ethyl acetate in a still equipped with a stirrer and partly filled with water. The ethyl acetate dissolved the nitrocellulose, making a lacquer not miscible with water. The stirrer broke the lacquer up into small globules, like shaking water and oil together. Raising the temperature of the water boiled off the ethyl acetate, leaving a round sphere of nitrocellulose. A protective colloid kept the spheres from sticking together. Further treatment drew the excess water out of the grain, making it more dense. The surface was then coated with nitroglycerine, which dissolved into its surface. This was followed by a layer of di-butylphthalate to control burning rate. The process produced varying ranges of grain

sizes, which were separated by screening. After drying and coating with graphite by tumbling, testing began to check the burning characteristics of the various grain size cuts. Blending of the various cuts to give desired overall burning characteristics produced the final product.

Burning characteristics can also be changed by passing the Ball powder grains between rolls to flatten them slightly. A ball, or sphere if you will, has a minimum surface versus its weight. By flatting the ball, the surface area is increased thus making the powder burn faster.

In 1939 and 1940, the Ball powder process was still in the pilot plant stage. The war was heating up in Europe and the British were at last becoming aware of the necessity of preparing for war. The British Government worked out a deal with Western Cartridge to erect a full scale powder plant utilizing the Ball powder process. In one of the more or less unsung but major contributions to the overall war effort, a full scale powder mill was up and in operation in about a year. As well as producing powder for the British, it later produced almost all of the powder used in the .30 Carbine ammunition as well as large quantities of .30-'06 powder.

The Ball powder process has an advantage over extruded powder—simple chemical jacketed stills, easy to fabricate, instead of costly elaborate blocking and graining presses and other special machinery made only to special order for extruded powder. Lead time in setting up a Ball powder plant is relatively short as a result.

On the other hand, the Ball powder process doesn't lend itself to rapid and frequent changes from one powder to another. It works best on long runs. But, as personnel get accustomed to the operating conditions needed for the various speeds, change-over does become less of a chore.

After the war, the plant reverted to a commercial status and worked to make the large variety of powders needed to fit the Winchester-Western cartridge line. In the beginning, the powder mill was not always sure when starting a batch of powder that it would turn out quite as intended. The ammunition side of the business was, of course, used to using Hercules and DuPont powders and was reluctant to accept any Ball powder that didn't exactly meet performance levels that had been achieved with the other long-established powders. There was at one time or another considerable verbal traffic and sharply worded communications between the two departments. Miller Hurley, the ammunition plant manager, on one occasion opined that the powder people made powder about like a new blacksmith would treat a piece of iron. The blacksmith would heat the iron up and beat on it—if it split it became a fork, if it didn't split it became a shovel. At any rate, as experience accumulated, the ability to produce powder to exact specifications developed and grew.

The powder mill, with its old hands, many of whom had been there for 20 or more years, was a fine educational institution, particularly in the field of safety. Most of the men there had been through one or more "blows" and were safety conscious. In designing the smokeless powder buildings which were required for doubling the capacity, I was fortunate enough to draw on the experience of these people and learned a great deal about making explosives reasonably safe to live with.

Blackpowder manufacture is immensely more hazardous than smokeless, and the lessons learned from many earlier explosions carried over into the smokeless plant.

The plant was actually a very safe place to work. According to records, on one occasion during the war, some 2 million man hours went into the plant before a lost time injury occurred. When the string was finally broken, it was because one workman had stubbed his thumb on a grinding wheel—not an explosion. A recent employee publication just received from Olin features a new record for the Winchester Ammunition Operations. The plant has worked 10,000,000 man-hours without a lost-time accident.

Now, to get back to the subject of powders and their selection in loading ammunition. Most reloaders, when they use a certain powder, think of it as being a fairly standard item with little variation from can to can. This is true of the so-called "canister" lots, that the powder companies furnish for reloading purposes. These lots, carefully blended to produce standard results, cost more to produce than the run-of-the-mill lots normally used by the ammunition companies. The extra testing and blending and, of course, smaller, more numerous containers bring the price up. Because the loading companies can measure and control pressures and velocities, they can work with a reasonable amount of variance from lot to lot of a given powder.

The loading companies also purchase powders of many different speeds, that are not sold on the reloading market in canisters. Hercules, for example, offers Red Dot to the ammunition companies in a choice of 10 or more speeds, ranging from a relative quickness of 105.9 down to 84.7. Likewise, Herco is offered in 10 or more different speeds. Reloaders can purchase only one dozen Hercules powders—one blend of Red Dot, having a specified relative quickness, one more of Herco, Bullseye, Unique, the ReLoder series, etc. By the same token, IMR Powder Company, in Plattsburgh, NY, only markets a relative few of the powders that EXPRO Chemical makes. Sales volume of cannister lots simply does not warrant all of these powders being offered for retail sale.

A big ammunition company, loading both shot-

shells and metallic cartridges, needs a great many different types and speeds of powder, sometimes as many as 65 or 70, for combined rimfire, shotshell and centerfire loadings.

The considerations are cost, availability, alternate powders, and, of course, the ability to match a powder to a load for good performance.

Powder is expensive, and a grain or two saving per load, not so much of interest to a handloader, can add up to many dollars in the course of a year's loading of centerfire ammunition or shotshells. On a 30 million round volume of centerfire cartridges, one avoirdupois grain, saved per individual powder charge, amounts to two tons of powder available for other uses. On 100 million rimfire cartridges, a 0.2-gr. change in powder charge adds up to nearly 3000 lbs. Hence, the loading company's care in selecting powders.

In choosing a powder for a load, the pressure-velocity relationship is usually the first consideration. With the number of gas operated shotguns and semi-automatic rifles in use today, a second consideration is port pressure.

For gas operated firearms to work successfully, the gas pressure at the port must be within a workable range. Too high a port pressure means drawing off an excess of energy to be absorbed by the gas system, resulting in over-stress, wear and possibly breakage. If not enough gas is delivered at the port, because of low port pressure, there won't be enough energy to work the action.

In checking out this kind of a situation, it is necessary to use a pressure barrel with two pressure pistons or gauges, one in its normal position at the chamber, the other down the barrel at the point where the firearm's gas port is located.

Fortunately, there is some latitude in the port pressure requirements of various rifles. A gas operated semi-automatic sporting rifle is expected by the user to accommodate the full range of bullet weights available in the caliber, and with all brands on the market. It follows that the manufacturer will have so designed the rifle, testing it with all ammunition choices.

An ammunition maker, making a change in an established load, must check the load, both as to port pressure and by actual function testing on the rifles in use.

Service ammunition for the M16 rifle has a breech pressure specification of a maximum average of 52,000 C.U.P. The port pressure specification is 15,000 ± 2,000 C.U.P. Note that, while the chamber pressure has only an upper limit in the interest of safety, the port pressure has both an upper and lower limit in the interest of proper functioning. The C.U.P. stands for Copper Units of Pressure, and is of the same order as pounds per square inch. C.U.P. is more fully explained in Chapter IX in the section on pressures.

Something of the same pressure and powder speed requirement can arise with other semi-automatics. The Winchester Model 50 shotgun, with its floating chamber, had a problem with Canadian Industries, Ltd. trap and skeet loads early in its history. Some Canadian shooters reported failures of the action to open fully with resulting jams. The floating chamber with its short .105" stroke wasn't getting moved fast enough to provide the energy needed to finish all the things the action had to do—extract the fired shell, eject it, cock the hammer, release a new round from the magazine, lift it into position, feed it into the chamber, and lock the action.

An examination of the ammunition in question indicated that the ammunition, as was usual with CIL, gave good pressures and velocities, but the pressure-time curves showed the powder speed a little too slow for the Model 50. The powder was Red Dot, which is sold to the ammunition maker in a choice of different speeds as mentioned earlier.

The Model 50 depended on a quick rise in pressure to move the floating chamber back at a satisfactory velocity.

In this case, since actual malfunctions were on the order of frequency of less than 1 in 100 shots, powder speed was almost, but not quite, fast enough. Upon request, CIL graciously ran a series of tests, found the change reasonable, and agreed to use a lot of Red Dot that gave a little faster rise to peak pressure. The quality of the ammunition was not compromised, nor was the cost of powder increased. The shooters were mollified, and the turmoil subsided.

In selecting a powder, the loading company has to think of other things besides pressures and velocities.

Small bottleneck cartridges, such as the .222 and .223 Rem., require a short-grain powder or a ball type of powder to pass rapidly through the neck without binding. Otherwise the loading operation would be slowed down. Also, a coarse grain powder in a light powder charge might suffer considerable variation in measuring by volume.

Too low a charge of too slow a powder can lead to hang-fires, poor ignition and wide variation in velocity. Low pressures also lead to quantities of unburned powder, which tend to clog up the action, particularly on semi-automatic and pump-action firearms. Powders which are too fast and loaded up to near peak pressures give pressure results which can vary considerably as well. Powder such as Red Dot, will burn cleanly at pressures around the 9,000–10,000 L.U.P. level. A rifle powder, such as IMR 4064, does not burn well and tends to give hangfires if the pressure level drops down into the 30,000 C.U.P. range. In rimfire cartridges, powders which are too slow will not obturate the case quickly enough and a certain

amount of powder will lead to the rear, blackening the case, causing some loss in velocity, dirtying up the action, and in extreme cases blowing some gas back in the area of the shooter's face. This in the factory is known as "blow back," and is entirely different from a burst head. The blackened case is a tell-tale sign.

Shotshells, with their wide variety of shot charges, shot sizes and degrees of hardness, pellet velocities, shell lengths, wad choices, and gauges, need a number of different powders for efficient loading.

At their relatively low pressure levels, up to a mean of 11,000 or so L.U.P. (*L*ead *U*nits of *P*ressure, see Chapter IX), shotshell pressures cannot be allowed to vary too widely from shot to shot on the low side of the average. Powders do not burn well at pressure levels much below their intended use levels. Odd bloops, sounding like shooting down a rain barrel, result if shotshell pressures drop too low for any reason.

The "rain barrel" shot, a hollow boom, means that the powder was not well ignited before the shot started down the barrel. The powder then burns slowly, doesn't reach a satisfactory pressure peak, and some is still slowly burning at the muzzle, giving the odd booming sound. On the trap field, fellow shooters look around with raised eyebrows. Hoodunit? Even worse, an outright squib can occur, leaving the shot charge and wad still in the barrel.

Loading to an average pressure level of, say, 7,000 L.U.P. with a 3-1⅛-7½ trap load can produce this result if there is any great variance in primer, powder charge, shot weight, wadding, in wad seating, or a soft crimp. Some of the resultant individual pressures would be too low for efficient burning.

Most commercial shotshells are loaded closer to a maximum average between 9,000 to 11,000 L.U.P. Very, very few squibs occur. Maybe one or two squibs or none occur in an average year of random shooting amounting to more than a million rounds, in one company. Velocities are more uniform at the higher pressure level.

Shotshell proof loads for testing shotguns are loaded to pressure levels averaging 18,000 to 19,000 L.U.P. Production loading around a 10,000 L.U.P. average poses no hazard of individual pressures being too high if variation in pressure from round to round is kept in control.

It pays to keep pressure levels up, as squibs are the most serious of shotshell malfunctions. A squib may mean wadding and shot stuck in the barrel. If not discovered and cleared, a following shot will, most of the time, burst the barrel. The wad itself may, but very probably will not, leave a ring in the barrel. The shot charge, however, is enough of an obstruction to cause serious damage. The barrel either swells out into a "dog knot" or bursts at the point of obstruction.

Occasionally, on centerfire cases of the bottleneck type, a failure to obturate, caused by a hang fire, might result in a partially collapsed case. What happens is that at the time of ignition, as the bullet leaves the mouth of the case, low pressure gas comes back around the case. The gas is trapped between the case and the chamber wall at the time that the cartridge pressure inside rises to its maximum. So long as the pressure inside the case is greater than the pressure of the gas trapped outside the case, nothing happens. As the bullet travels down the bore, the pressure inside the case drops and becomes lower than the pressure outside, at which time the expanding outside gas crushes the case inward. This is evidenced by a lengthwise dent in the case in the vicinity of the shoulder, as a general rule.

It must be remembered that in some parts of the world, ammunition is used in the field under considerable extremes of temperatures. For that son, the loading companies routinely check ammunition for ignition and pressure and velocity at temperatures down to minus 40° Fahrenheit or Centigrade—take your choice, they're both the same at that point. Ammunition is also checked at higher temperatures, representing those found in the tropical countries.

There was one case where .300 Mag. ammunition loaded with IMR 4320 or IMR 4350 (I've forgotten which) worked perfectly in the factory and was generally satisfactory in the field. However, Colorado, during the hunting season that year, had some unusually cold weather and some complaints of slight hangfires came in from the hunters. A further factory check at minus 40° indicated slightly slow ignition and a tendency toward hangfires, although not of the severity reported by the hunters, probably because the hunters fired a much larger cross-section of the ammunition than the factory did. The answer was a change to IMR 4064, which has a relative quickness of 120 vs. 100 for IMR 4350, or 110 for IMR 4320.

It must be remembered that the larger the case and the larger the powder charge, the more work the primer must perform in order to fire up the boiler.

Except for some of today's larger cases, however, today's primers are reasonably, but not perfectly, balanced in their performance from the smallest to the largest case in normal factory production. With too much primer on a small case, there might be some chance of over ignition. At the same time, with too little priming mix on a large case, there is some chance of under ignition. Present standard primers, as made by all manufacturers, are a compromise between too much and too little, when the smallest and largest cases are considered. It is for this reason that CCI developed its magnum

primer to give better ignition of large charges of slower burning powders.

In pistol and revolver cartridges, powder selection is not particularly troublesome. With the exception of magnum loadings, there is little chance of squibs, so long as normal pressure levels are adhered to. Extreme care must be taken, however, with certain powders in certain calibers where there is enough excess room in the loaded case to accommodate a double powder charge.

Double revolver charges can be expected to produce dangerously high pressures. A revolver loses a certain amount of utility when a chamber splits and the top strap gets blown off.

With the exception of the magnum calibers: .357, .41, and .44, and also 9mm Luger, almost all the common pistol cartridges can be production loaded with Hercules Bullseye. A great number of other powders will also work, as handloaders know. The magnum calibers call for careful powder selection, depending on the components involved.

Next to shotshells, rifle loadings call for the biggest variety of powders. Combining only those rifle loads offered by the four major U.S. ammunition makers, there are some 60 different rifle cases being loaded for sporting use. They range from the .17 Rem. to the .458 Win. Mag. Winchester, for example, loads 47 different rifle calibers. Remington, too, loads 47, and the lists are not duplicated, for Remington alone loads the 8 mm Rem.Mag., and only Winchester loads its .338. Federal and Frontier add their share—Frontier with the .220 Swift, Federal with the 7-30 Waters. And, to support all this variety, the ammunition companies can choose from a list of industrially-available propellants that numbers in the hundreds.

Today's high cost of maintaining an inventory presents another problem—this one in economics—that must be worked out. The powder that might be the least expensive for a given loading may not be needed in sufficient quantity to justify its purchase and retention in inventory. So, a more commonly used powder, that gives adequate ballistics, is substituted.

All three major North American powder makers, Hercules, Olin, and Canada's EXPRO Chemical Products Co.—that now makes and markets the former line of DuPont IMR powders—like to sell their powders, so it isn't necessary for the ammunition makers to sample all of the various powders available. Rather, they send components to the powder makers, for recommendations. Based on these recommendations powder samples are sent to the ammunition maker, for trial and verification.

It is normal for the ammunition maker to send periodic samples of bullets and cases to the powder maker, for routine testing of powder furnished to orders, as well as for testing new powders and new components. With each lot of powder shipped, comes a ballistic test record showing the results of the powder maker's performance tests.

There are two basic powder types to consider in centerfire loading: the conventional tubular-grain, single- or double base powders; or the newer Ball powder, developed shortly before World War II.

Either General Rodman back in the Civil War days was a good ballistician or he had some smart lieutenants. The invention of the progressive burning powder grain, attributed to Gen. Rodman, paved the way for today's high velocity cartridges. The tubular grain, with a hole down the center, provides the progressive burning rate that gives an accelerating push to the bullet as it moves down the barrel. As the outside of the grain burns, its external area decreases, but at the same time the hole through the grain is increasing in diameter and corresponding area, giving an increasing volume of powder gas. Temperature and pressure are rising, both acting to make the grain burn faster, progressively.

Ball powder is also made to burn progressively, but by chemical means. As the surface of the ball burns, its area decreases, which would create a digressive burning situation, unless the outer surface is treated to make it burn slower than the inner layers. The ball-like grain is treated on its outer surface with a deterrent to burning, somewhat fireproofing the grain in the process.

Once deterred layers are burned off, chamber pressure and temperature have increased to a point where the undeterred inner parts of the powder grains burn very rapidly. The overall effect is that of an increasingly higher pressure application to the projectile.

In the overall energy balance, the deterrent, usually di-butylphthalate, doesn't provide much of the horsepower the powder charge delivers. To begin with, it is a liquid and takes calories to change to a gaseous form. Then it is oxygen deficient in a situation where the far more active nitrocellulose is also oxygen deficient. In other words, beyond slowing down the initial burning rate, the DBP is more or less dead weight, and expensive at that.

In general, therefore, it takes a little heavier powder charge with Ball powder to get the same velocity that a tubular powder of similar speed would give, granted the energy content of the nitrocellulose and nitroglycerin present is the same.

In 5.56 mm M193 military cartridges, the Ball powder frequently used requires a 26.5- to a 27-gr. charge to reach a standard velocity of 3250 f.p.s. A tubular Nobel powder furnished by ICI gives the same velocity with a 24.5-gr. charge.

Unless there is a corresponding difference in cost per pound in favor of the ball powder, the cost advantage would clearly be with the tubular type.

There is, however, another consideration. The old expression "nothing rolls like a ball" applies here. It might be added that nothing packs quite so uniformly as a bunch of balls.

On an automatic loading machine, the powder charge is metered by a sliding chamber which moves back and forth from powder reservoir to powder drop. Powder has to flow quickly and accurately into the charge chamber, and then flow quickly down the small neck of the 5.56 mm case. This flow has to be faster than the delay time provided for powder drop on the machine, or the powder charge won't get in the case. Slowing the machine down limits the production rate.

Here, Ball powder has the double advantage of charging more accurately and filling the case more quickly. This advantage is partly overcome by making the tubular grain very short. The resulting tubular powder charge uniformity is generally satisfactory. The loading machine can operate at near Ball powder loading cycles. On larger calibers, the powder flows more easily through the neck. In automatic military weapons, machine guns, Ball powder produces less bore erosion, another advantage. The powder burns a little cooler because of the deterrent.

As was mentioned above, the Ball powder grain is somewhat fire-proofed by the deterrent coating, which makes ignition and subsequent pressure rise difficult to keep under control through a wide range of loading conditions and calibers. The speed of the Ball powder used must match the load very closely, at which point performance is equal to that of any other powder.

In this regard, Ball powder lacks to some degree the "flexibility" that most tubular types have. The tubular type of powder can be used within a wider range of average pressures and loading densities. A corresponding Ball powder of the same speed may run into weak ignition and subsequent low individual pressures on one end of the scale, and very rapid pressure rises for a small change in powder charge at the other end of the scale.

When WC 295 Ball powder first came out as a canister powder for reloading, it had had extensive testing in the factory, but only with W-W components. It was developed and used in the factory for loading .44 Mag. ammunition. After several thousand cans had been sold, complaints of squibs, weak shots, and even of bullets remaining in the barrel, began arriving. Calibers other than .44 Mag. were mentioned.

Extensive rechecking showed that the powder would give these results with some competitive primers. Even with the factory's own primers, tested at −40°, certain calibers gave squibs and low reports, indicating that ignition was borderline. This was a prime example of lack of flexibility. The powder simply wouldn't ignite well with some commercial primers available to the reloader, and only worked well in one caliber, .44 Mag., and only with Winchester components. The slightly faster 296 powder has since been more successful. WC 295 was discontinued as a canister powder.

Out in Idaho, on one elk hunt, I had an experience that brings out one aspect of the Ball powder grain. My field transportation in those days was an International Harvester Scout. In the early model, the exhaust pipe ran very close to the floor on the passenger's side. The area under the front seats was enclosed and unventilated, so that it got very warm. Once in a while a loose round on the seat found its way down inside and got thoroughly warmed up. My son reported that it was quite a puckering sensation to have a loose round go off underneath him, while driving along. He produced a well mangled case to prove the point. Later, as *Figure 52* shows, it happened to me.

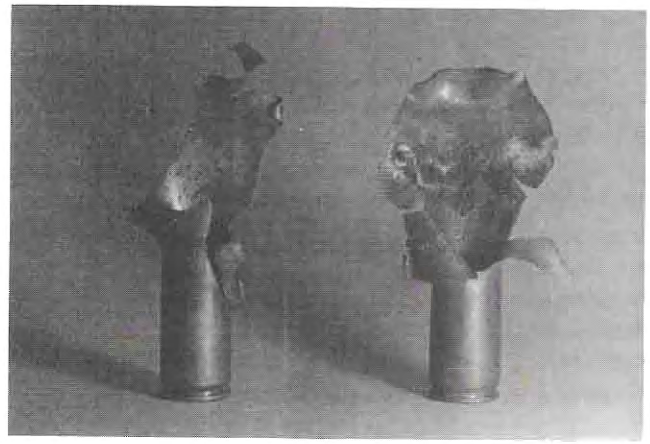


Figure 52

However, not all of those rounds went off. In cleaning out the car one day, I picked up a .308 Win. round off the floor and dropped it in my pocket. A week later, up in elk country, I was heading back to camp about dark when I saw, against the fading sky, the silhouette of a blue grouse in a tree. I carefully shot its head off, noticed the report was a bit odd, and found that my Model 88 lever action wouldn't open. Back in camp, the bird was a very welcome addition to the pot, but I had a problem—no spare rifle, and this one was locked up really tight.

Finally, using the point of a screwdriver and a hammer, we managed to rotate the locking lugs enough to get the bolt open and the case came out with it. Looked like high pressure: primer dropped, primer pocket badly expanded, and head ballooned out. Case did not seem soft. Big puzzle, until I recognized the case as the discolored one picked up from the Scout.

The continuous high heat under the seat had apparently caused the deterrent to migrate from the surface into the interior of the grain, resulting in a drastic increase in burning rate for the powder.

Fortunately, no damage to the gun. Moral: Don't leave ammunition out in the burning sun or in an active oven—it doesn't improve it. I don't know how long this cartridge had been heated or to what temperature, but one should not expose any ammunition to elevated temperatures for any length of time. Here in the Philippines, for instance, surface temperatures get up to well over 150°F (65.5°C) in direct sunlight.

Speaking of high pressures, it is interesting to note that years ago there was trouble with certain high nitroglycerine powders at low temperatures. Reports were coming in from Northern Canada, during a very cold winter, that some rifles were being blown up.

Usually, of course, at low temperatures, pressures are also low. The complaint rifles showed damage typical of very high pressures. At normal temperatures, returned cartridges, however, showed no signs of high pressure.

The answer in this case was that when the powder got very cold the nitroglycerine in the grain froze and wanted to crystallize, which weakened the grain. The primer flash drove the brittle grains forward, causing them to shatter, giving the same effect as a fine grain fast burning powder. Modern double base powders are now plasticized so that this no longer happens, and, after more than 40 years, all the old loads are gone. No more trouble.

In centerfire cartridges, it is well to select a powder that fills the case as nearly as possible. With a large amount of air space in the loaded case, pressures and velocities vary more than normal, depending on whether powder is at the primer end of the case or at the bullet end. Pressures are usually, but not always, lower with the powder at the bullet.

Again, as reloading has increased, more and more often cases are reported where low powder charge loads produce occasional extreme pressures, almost as if the powder detonates rather than burns. There are several theories as to why this near detonation occurs. I have yet to see, however, an explanation verified in actual practice. Too many rounds would have to be fired to prove the point, as frequency is extremely low.

Many people believe, myself included, that pressure waves in some sort of resonance create local ultra high pressure zones in the cartridge case which affect the normal burning rate of the small charge of powder. This is not a new situation. Unexplained pressure excursions were reported more than 60 years ago, and there was no answer then.

In any event, it remains good practice to keep the case well filled with powder.

Table 6 lists one ammunition factory's choices of powders for specific cartridges and bullet weights, ca. 1960. Though now nearly 30 years old, this list is typical and representative. Powder charges are not listed, since the ammunition companies do not use standardized "canister" powders. Powder charges for non-canister, commercial lots of powder vary slightly from lot to lot.

Table 6
Typical Powder Choices

Shotshells	Load	Powder
12 ga.	3–1⅛—all shot sizes	Red Dot 40
16 ga.	2¾–1⅛ " " "	Herco 110
20 ga.	2½–1 " " "	Herco 140
Rimfire		
.22 Short	High & Std. Velocity 29-gr. bullet	Hercules 950
.22 Long	High Velocity 29-gr. bullet	" 1050
.22 Long Rifle	High Velocity 40-gr. bullet	" 1293
.22 " "	Standard Velocity 40-gr. bullet	" 950
.22 " "	Match 40-gr. bullet	" 950
Centerfire Pistol		
.38 Special	148, 158-gr. loads	Bullseye
.357 Magnum	158-gr. lead	295 Ball
.44 Magnum	240-gr. lead bullet	295 Ball
.45 Automatic	230-gr. metal case bullet	Bullseye
.45 "	210- & 185-gr. match bullet	"
Centerfire Rifle		
.222 Rem.	50-gr. bullet	IMR 4475
.243 Win.	80-gr. bullet	" 4350
" "	100-gr. "	" 7816
.270 "	100-gr. "	" 4064
	130-gr. "	" 4350
	150-gr. "	" 4350
.30-.30 Win.	150-gr. bullet	" 3031
	170-gr. "	" 4895
.30-'06 Springfield	All loads	" 4064
.300 Magnum	150-gr. bullet	" 4350
	180-gr. "	" 4350
.308 Win.	110-gr. "	" 4475
	125-gr. "	" 4475
	150-gr. "	" 4320
	180-gr. "	" 4320
	200-gr. "	" 4895
.375 Magnum	270- & 300-gr. bullet	" 4064
.458 Win.	500-gr. bullet	" 4475

Not all propellants have been either black or smokeless powder. Other mixtures have been tried, but with not much success. Two shotshell powders, which come to mind, but which were gone before my time, are examples:

One powder, called "Gold Dust" dates from the early 1900's. The name obviously came from its color. The principal ingredient was picric acid, nitrated phenol or carbolic acid. Picric acid, like its close cousin, styphnic acid, is a bright yellow dye. This powder was used in some shotshells. There

were, besides a not very imposing performance, two distinct disadvantages.

The powder didn't burn completely, ejecting gaseous carbolic acid along with other material. On a damp, foggy day, with the wind against the firing line at trap, weak carbolic acid blew back in the eyes and faces of the shooters. The other disadvantage was that some unburned picric acid also blew back, adding bright yellow color to the scene. On the face or on the clothing, the yellow didn't easily wash away. These two things caused some discontent, and the powder, yellow and all, faded from the picture.

The other powder was a horrible mixture of potassium or sodium chloride and sugar. The formula was the sort of thing advertised in "Uncle Billy's," "Whiz Bang," and similar magazines, where you sent in a dollar, thereby saving untold sums. The same entrepreneur, or a relative, was probably the one who, back in horse and buggy days, advertised a method of stopping the horse from lathering both itself and the hapless passengers back in the buggy. You sent in a dollar and back came the magic solution, "Teach your horse to spit."

One of the machinists at Western got the formula, made up some loads and arrived at the company trap field with his Model 97 Winchester. According to the story, he announced his new find, stepped up and fired his first round, successfully. The second round blew the breech block nearly out, ending the trial for the day. There should have been some sort of message there, but wasn't. The mechanic showed up the next Saturday, with his shot gun repaired, and more of the same loads. There was an additional feature added, however. A stop block had been added just back of where the bolt stopped when fully open. This was done in case the bolt didn't stay where it belonged, and on the first shot, it didn't. Breech block, stop and all whizzed past the machinist's ear, utterly destroying his confidence in the new powder, also ruining his M97.

This powder too passed into history.

CHAPTER VIII
LOADING

Granted that the components are well made and uniform, the process involved in loading quality ammunition is not very difficult. A charge of the correct propellant has to be uniformly metered. The bullet must be seated square with the long axis of the shell, and to the correct overall cartridge length. Bullet pull, adjusted by crimp, has to be set and held within prescribed limits. These steps complete, and provided the loading process hasn't damaged primer, case or bullet, the job is done.

In simple terms, the loading operation is one of packaging a granular material—the propellant—in a brass or plastic bottle—the case or shell—sealed with a special, tight-fitting plug—the bullet. Shotshells add an additional material—the wad—somewhat akin to stuffing cotton in a medicine bottle to keep the pills from rattling. A crimp is used to seal the open end of a shotshell instead of plugging it with a single bullet.

The most critical step in rimfire loading is seating the bullet, for that has greater effect on accuracy and performance than in the case of a centerfire. Also, the small amounts of powder, each about 0.00029 pound for a .22 Long Rifle cartridge, require special care in measuring for good uniformity. Crimping is the most complicated operation.

Controls over loading, handled by the ballistics lab, include pressures and velocities, random shooting and accuracy.

Bullet pull and powder charge weight are necessarily checked in close proximity to the loading machines, so that the feedback of information and subsequent adjustment wastes little time. Rimfire ammunition needs a close check on final bullet diameter and tightness of the bullet in the case.

Overall length and tightness of rimfire crimp are checked at the loading machines by roving inspectors, as well as by operators. Centerfire bullet and case alignment or concentricity are also checked at loading by roving inspectors.

Damaged or mutilated cartridges are watched for at the time of loading. Loading machines sometimes get out of kilter and spoil a few cartridges before the trouble is noticed. Scrap at this point is costly.

Later the ammunition will, if centerfire or shotshells, undergo a 100% visual inspection. Rimfire cartridges, being too small and too numerous to examine individually, are eyed closely as they are being packed, as well as at the time of loading.

Machines and Methods

As thousands of handloaders can testify, loading can be done on hand-operated presses. For a small company, producing limited quantities of only a few calibers, these tools are useful. Low capital investment, rapid set-up and easy operator training partially offset high labor costs. Certainly, if and when volume picks up, a change to a more efficient machine has to be made.

When labor costs are still low, as they are here in the Philippines, a sort of "quilting bee" works quite well for low volume items. One operator charges cases, using any one of several popular makes of powder charger. One operator starts the bullet in the case, and a third uses a "C" or other type press to seat and crimp, as for .38 Spl. Such a set-up can produce 8,000 cartridges per shift. Capital expenditure for loading equipment can amount to less than $500.

Similarly, in the Philippines, as the sales of .22 Magnum Rimfire were developing, a modified plate loading, hand charging and seating set-up produced up to 8,000 cartridges a shift with labor costs only running 6.84 pesos per thousand ($.32 at today's exchange rate). An operator picked up a case, charged it, set it in a small plate with 25 holes. Operator number two added a funnel plate filled with bullets and seated them all at one time in a shielded kick press. Operator number three fed them one at a time through a crimp press, hand-operated.

Full-scale plate loading only expands what was being done for .22 Magnum Rimfire. Fully manned, a simple .22 rimfire plate loading line, operating at maximum efficiency, can produce up to 400,000 cartridges a shift, using only four people: a case shaker, a bullet shaker, a powder charger, and a crimper operator.

Squires-Bingham designed and made its own simple loading line of two shakers, a powder charger, a bullet seating press, and a crimper for a total cost at the time of about $5,000. This line would easily produce 200,000 cartridges per shift, and could be changed to increase production by simply increasing the capacity of the plates from 500 to 1,000 cartridges. Four people manned the line. Volume was sufficient to handle the company's needs for several years. Growing volume prompted a change to larger units purchased from Eley Ammunition in Australia. The older unit stays in reserve.

Right alongside the plate loading line at Squires was a Manurhin loading machine, that cost $35,000 in 1964. With two operators, the machine could produce a maximum of 70,000 to 75,000 rounds a shift. The Manurhin is actually a good centerfire loading machine, but when tooled for .22 rimfire, it is unnecessarily complex and a little slow.

The seven plants, in which I've seen plate loading done, all follow the same basic scheme, yet all are different in machinery design. As at Squires-Bingham, all the plants essentially, over a period of years, developed and made or had made their own machinery for plate loading.

Rimfire Plate Loading

Except for the size of the plates, and the number of cartridges per plate, plate loading works as well for centerfire cartridges as it does for rimfire. Indeed, except for size, the assembly machines are nearly the same for rimfire or centerfire ammunition.

Bullet Shaker and Plate

Two shakers are needed: one for bullets, one for cases. The operator begins by laying an empty plate in the bullet shaker, where the shaking motion is lateral. He then reaches into a reservoir underneath the shaker and loads several double handfuls of bullets onto the moving plate. The bullets drop nose down into the holes in the plate. When the plate is full, the operator lifts it, rolling the extra bullets back into the reservoir. Any bullets that fall into the holes base downward are reversed. The plate of bullets is inspected for any defective bases, and any that are found are replaced. A cover is then slid into the grooves at the edge of the plate, covering the bullets, so that the plate may be turned over for following operations.

This sounds simple, and it is except for one thing. The pace of the overall line depends on having all, or nearly all, the bullets tumble into the holes in the plate nose down, saving time in reversing those that fall nose up. How to get the bullets to fall properly is a function of plate motion, bullet shape, hole spacing, hole shape, and the number of bullets on the plate. The plate that works well with one bullet may not work well with others (See Fig. 53).

The bullet plate has locating pins on two opposite corners, which in a later step fit holes on the case plate.

After fitting the full bullet plate on the charged case plate, the coverplate is pulled out, letting the bullets drop, base first, into position over the mouth of the case, previously charged with powder. The bullet plate is then removed and goes back to the shaker for refilling. The case and bullet shakers normally accommodate two plates, so that the operator needs to spend less time in waiting for a plate to fill. One plate is always ready.

Case Shaker and Plate

As with the bullet shaker, case shaker motion is lateral. A reservoir underneath the plate holder holds primed cases.

The shaker plate is placed on the holder. Several handfuls of cases are dumped on the plate and fall, usually head down, into the holes in the plate. Hole diameter is larger than the case head diameter, so that the cases may fall in easily.

There is a way to short-cut time-consuming reversal of cases which fall mouth down. The bottom cover of the shaker plate has an odd shaped hole which holds the case which falls head down, but lets a case falling mouth down drop on through. This lets another case, hopefully head down, fall into place. If not, the process continues until the proper case is in place. Such a cover plate hole is shown in *Figure 53, Step 1.* The contour of the caseplate is shown in *Figure 53, Steps 1 and 2.*

After the plate is full of cases, it is picked off the shaker and the cases are inspected for defective mouths, length (too long, too short), and missing primers. Defective cases are picked out of the plate and replaced with good ones.

Next, the case plate, again with two pins at opposite corners, is fitted to a funnel plate, and the two plates inverted so that the cases fall, mouths down, into the funnel plate. The case plate is removed and goes back to the shaker.

Funnel Plate

The funnel plate serves to hold a case in position to receive its powder charge, and later to align the bullet with the case mouth so that the bullet may be started and seated accurately in the case.

The funnel plate has grooves on its bottom side, next to the case shaker plate. After the shaker plate is removed, a cover is slid into these grooves and the funnel plate turned over so that the cases in the funnel plate are oriented mouth up. The funnel plate, full of cases, goes to the powder charger.

A cross-sectional view of a typical funnel plate is shown in *Figure 53, Step 5.*

Powder Charging

The simplest powder charger needs two plates; a sliding upper, or charge, plate with raised sides to keep powder from dropping over the edges, and a lower, or transfer, plate that acts as an interface between the charge plate and the funnel plate.

The charge plate has one charge hole for each case in the funnel plate. This plate slides a little over the width of one charge hole to a blank spot on the transfer plate to close the bottoms of the charge holes.

The transfer plate is fixed. Each hole is lined up

over a corresponding hole in the funnel plate, which is slid in place directly beneath.

The charge plate is filled by sweeping a small pile of powder the length of the plate. Powder drops into each charge hole as the sweep passes. Care must be taken to keep the sweep vertical so that it doesn't squeeze powder into the charge holes. The powder must be allowed to drop evenly and uniformly. The pile of powder must be moved across the charge plate at a constant rate, and the rate must not vary from charge plate to charge plate.

When a charge is needed that is a little heavier than normal, the charge plate may be rapped one or more times after filling, to settle the powder in the charge holes. The holes are then filled completely by sweeping the powder across them a second time.

After filling, the charge plate is moved forward so that the powder charges drop through the transfer plate and into the corresponding holes in the funnel plate, and thence into the cases. The charge plate is then moved back to receive fresh charges, while the funnel plate, now full of charged cases, is detached and sent to the next station.

Under a careful operator, the powder charges can be very evenly distributed in each charge hole. In rimfire high velocity cartridges, the individual powder charges weigh about 2.2 grs., and occupy about 1.8 cc each. The variation between individual powder charges, given a careful and skilled operator, will be about .16 gr., in a sample of 50. Statistically, the standard deviation of the charge weight will run about .04 gr. Careless, sloppy charging will increase this variation considerably.

In the simplest charger, charge weight is regu-

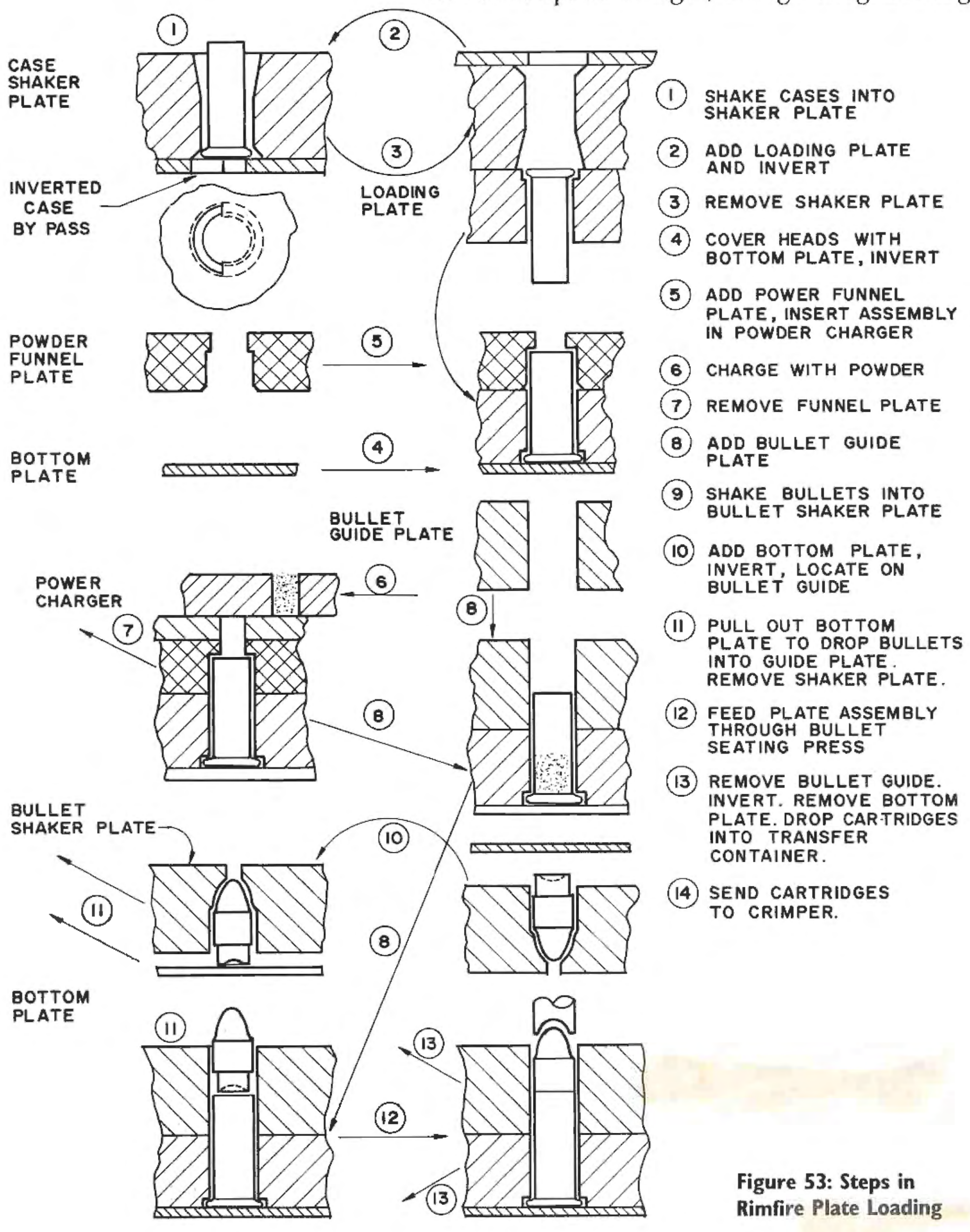


Figure 53: Steps in Rimfire Plate Loading

lated by changing the thickness of the charge plate. A more complicated plate may be made, which can be adjusted to vary charge weight, if it is desired. In fact, this operation may be made about as automatic as the ingenuity of the machine designer will permit.

A still more complicated charger adds one more plate, atop the charge plate. This plate is fixed. Its holes coincide with the charge plate when the charge plate is in the closed position, after the powder charges have been dropped. Fresh powder from a reservoir above drops through the upper plate, into the charge plate. Powder flow is cut off when the charge plate moves forward to drop its charge. Vibrators or rappers must be added to make sure powder flow is uniform.

Another type, the Eley charger, is more complex mechanically, but easier to make charge plates for. It charges very accurately. The charge plate has two rows of holes, arranged to run across the width of the funnel plate, and a top-mounted powder reservoir. The funnel plate, below, indexes a row of charges holes at a time. One row of holes in the charge plate drops its charges while the other row is being filled. A rapper jars the powder down to make sure that the charge holes are being filled uniformly. Powder level in the reservoir is kept within close limits to make filling of the charge plates more even (See Fig. 54).

Powder Detector

After charging, the plate of charged cases may or may not pass under a powder detector. It's up to the manufacturer. In a detector, a probe drops into each case in the plate. One end of each probe rests atop the charge in each case—usually, in one row of cases. If all the charges in that row are okay, the plate indexes so that the next row can be checked. If, however, there is too much or too little powder in a case, or no powder at all, the misaligned probe at that point will cause the machine to stop, and generally give some signal that it has done so. The machinery must be continually adjusted and readjusted to accommodate minor changes in charge weight, and needs constant checking in insure proper operation of the automatic stop mechanism and the probes.

The principle value of the powder detector is that it finds big errors—large numbers of uncharged cases such as might occur if a powder reservoir were to run out of powder, or if the operator on a hand operated charger skips a plate. There is also a lesser chance that a stray piece of foreign material will plug a charge hole, leaving an empty case that the detector will find.

One of the necessities in the loading operation, particularly if work is performed on the night shift, is complete protection from insects. A small mosquito, or a bug of any kind, that gets into a cartridge case and is loaded along with the powder and bullet, will cause a misfire if it's left there for any length of time, as it naturally would be. Likewise, eating on the assembly line is forbidden. A piece of ham sandwich has the same effect on a loaded cartridge as does a bug—it ruins the round.

In place of a powder detector, a visual inspection is quite satisfactory. A keen observer will notice charge levels that are much too high or too low. And a row of bright shiny, empty cases in an otherwise fully charged plate (or even a single empty in a full row) is easily spotted by an alert inspector.

After inspection, the cases go to mouth spreading.

Mouth Spreading

At some point in the process, before the bullet is seated in the case mouth, the mouth must be "belled" slightly. As a result of the sharp trimming knife, the mouth of the case is left with a sharp edge inside. This edge will shear lead from the heel of the bullet, spoiling accuracy. So, as the case is finished, or during the loading process a punch is run into the mouth of the case just enough to bell it about .0025". *That* this step is taken is much more critical than *when* it is taken. Belling can be carried out by an additional punch on the priming spinner, if the spinner is of the indexing dial type. Or, belling can be done during the plate loading operation, prior to powder charging. The difficulty in the latter instance is the need to set multiple punches to the same height so that mouths will be belled uniformly from case to case.

The spreading punch should have a pilot small enough to enter the case—a diameter of .2065' to .2070". The tapered portion of the punch should have an included angle of 25°.

After belling, the case goes to powder charging and bullet seating.

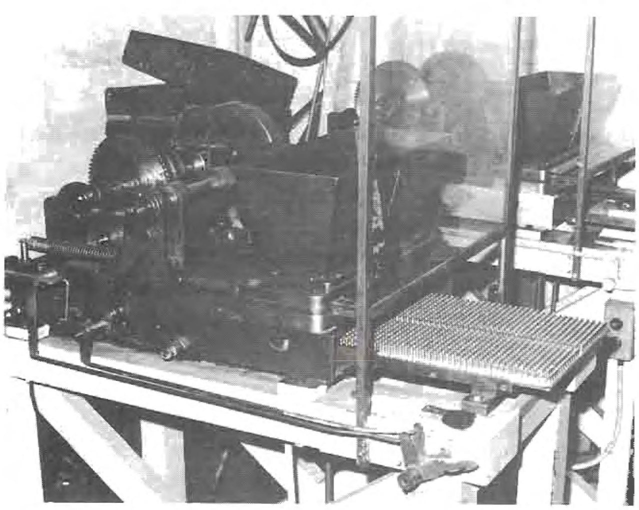


Figure 54: Eley Charger in Operation

Bullet Seating

Here is where the plate of bullets and the plate of charged cases meet. The operator places the bullet plate atop the case plate, aligning pins and holes at the plate corners. The intervening cover plate is withdrawn and the bullets drop into their respective holes in the funnel plate, lined up with the case mouths. The bullet plate is then removed and the funnel plate, filled with charged, bulleted cases, goes to the bullet seater. Bullet seaters may be of two basic designs. One, easily operated using an hydraulic press, has a seating pin for each bullet in the plate. The pins are shaped to fit the bullet noses. Locating the loaded plate under the press, the press is closed, forcing the bullet into the case to a prescribed depth for each of the cartridges in the plate, all at the same time.

The plate of assembled cartridges is withdrawn and the cartridges sent to the crimper.

The other bullet seater is a press operating on a ratchet and has a row of punches. Row by row, the punches descend on the cartridges, seating the bullets as the punches do in the hydraulic press, but only one row at a time. Between strokes, the ratchet advances the plate to the next line.

Occasionally, for various reasons, a cartridge will fire at bullet seating. Possibly the cause is a smear of priming at the case mouth, possibly a bullet jammed the mouth of the case causing its weight to crush the case head and fire the primer. When the cartridge fires in a plate of 500 or 1,000 in the single stroke hydraulic press, an explosion may occur as neighboring cartridges fire. Because the cartridges are closely confined between punch and press bed, and by the case plate, the explosion may be quite violent. Serious, even fatal, accidents have occurred on this operation through failure to shield press properly, and also because of lack of provision for pressure relief.

On the preferable row seating press, only one row is confined and pressed at a time, lessening the magnitude of any possible explosion by a vast amount. Pressure relief is also taken care of by having an anvil, against which the case heads rest, vented under the center of each head. If a cartridge fires, the head will blank out against the vent in the anvil, releasing pressure without firing adjacent cartridges. The same system would work on a hydraulic press, but it is complicated by the number of heads to be vented.

Controlling seating depth is easier on the row press, because there are fewer punches to adjust.

After seating, the cartridges go to the crimper. The empty funnel plate goes back to the case shaker.

Crimper

The functions of the rimfire crimper are to:

1. Close the case mouth around the bullet heel to keep the bullet in the case under whatever pull resistance is required. By means of a crimp knife, the mouth of the case is rolled inward against the bullet.

2. Seal the bullet-case joint with an extra push of lead down against the crimp. By means of a lead knife working just above the crimp, bullet lead is moved down against the crimp, tightening the bullet in the case, and making a better seal.

3. Knurl and size the bullet, and control its final shape and diameter.

Most crimpers are rotary (See Fig. 55). There is a drum which is powered for rotation. Opposing the drum is a block of steel curved to provide an evenly annular space through which the cartridge case rolls, rotated by the friction between drum, case, and block. The block can be adjusted to vary the annular space width. The drum usually also carries the knurling ring, which puts the knurl on the bullet.

On the block, three sections are provided. The first section carries the crimp knife which is closely adjusted to control bullet pull. The second section has an adjustable lead knife. The third section is smooth, but also finely adjustable to control final bullet diameter. Some provision can also be made in this section to modify bullet shape, as by sloping off the sharp nose shoulder left on the bullet by the forming punch. Sloping the shoulder reduces drag in flight, making the bullet lose velocity less quickly.

Setting the crimp is a step by step process.

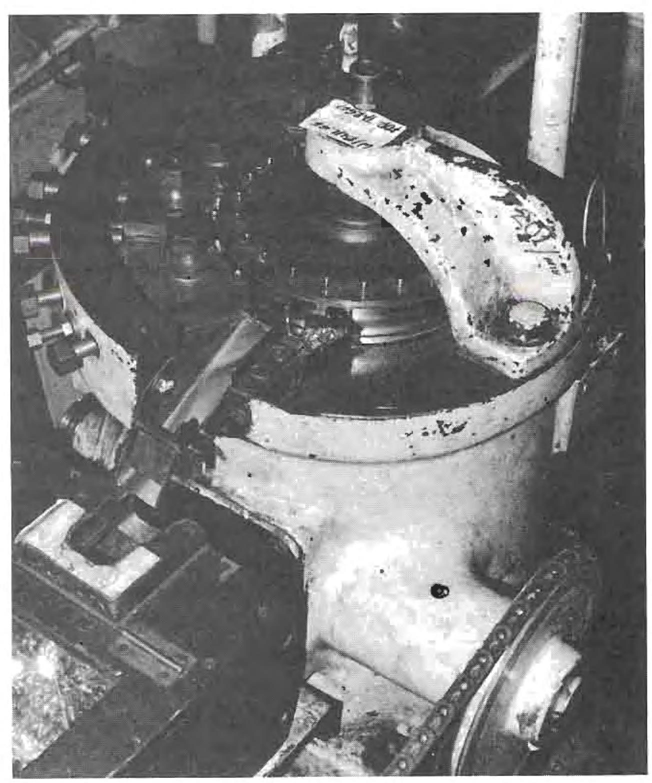


Figure 55: Rotary Crimper for Rimfire Cases

First, the case drive space is set by moving the block in or out. There is a slight lead-in on the block so that the case is gradually drawn in to the driving section. Care must be taken not to squeeze the case too much, as the bullet heels would be rolled to a smaller diameter in passing through.

Next, the crimp knife is gradually adjusted inward until the proper bullet pull force is reached. The crimp knife must also have a lead-in, so that the case mouth, beginning at the very top of the case, is rolled in gradually. Crimp knife angle is a matter of choice. A 30° angle is used by some, but is very critical of any variations in case lengths; 45° or 60° is more tolerant in this regard.

Next the lead knife is moved in. The lead knife is sharp, 30° or less. Its function is to push lead down against the crimp. This serves to make a tight seal between crimp and bullet, and to tighten the bullet in the case. The knife is moved in just far enough to make it difficult to twist the bullet with the fingers.

In normal use, a slightly loose bullet is really not harmful. Velocity and pressure will be no different than that of the other cartridges from the same group. The average shooter, however, tends to equate a loose bullet with a possible failure to shoot properly. Such a cartridge will have a tendency to absorb oil or moisture faster. Looseness is, therefore, to be avoided. Hence the lead knife.

In the final section, the bullet is rolled to proper roundness at the desired diameter. Any lead raised by the crimp knife or knurl is ironed out. Final bullet diameter should not exceed .2250", but nominal is .2235" to .2245".

Cartridges may be crimped head down or head up. Feeding head down requires a feeder to orient each cartridge as it is fed. The head up configuration lends itself to an easily fed, hand-fed crimper since the cartridges fall into the driving slot and are carried around on their rims by the drum to the crimp section. No feeder is necessary, but the operator must spend full time feeding the crimper (See Figures 56 & 57).

Either crimper configuration works well. As the crimp is apt to remove small fragments of lead, the machine must be kept clean by frequently brushing out the lead particles. In this regard, the head down crimper is more critical, since the lead particles interfere with cartridge heads resting solidly against the rotating bottom plate.

After crimping, the ammunition is lubricated.

Lubrication

.22 Rimfire cartridges, whether with plain lead or with plated bullets, must have some lubrication to prevent leading in rifle or pistol barrels.

For hunting cartridges, hunters prefer a dry, non-sticky or non-greasy lubricant, which doesn't gum up the hands, doesn't pick up lint and dust

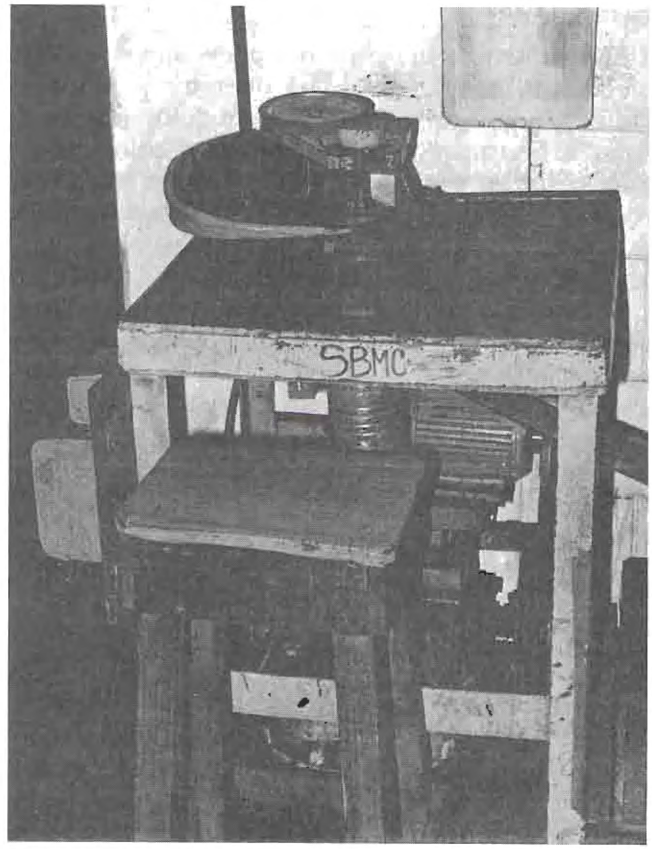


Figure 56: Hand Fed Rotary Crimper

easily, and which helps feeding as well as preventing lead deposits in the bore.

Match ammunition seems to achieve maximum accuracy with a greasier lubricant.

Application of lubricant may be by dipping the cartridges in melted lubricant, or by application of the lubricant in a liquid solvent. Either way has advantages and disadvantages.

Hot lubricant is apt to be smelly, gives off some smoke if overheated, and wastes the drop of lubricant that is wiped off the bullet nose. Hot

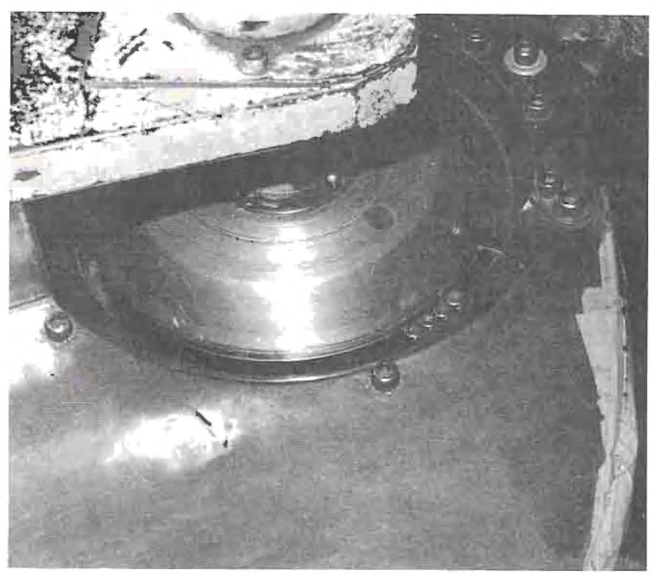


Figure 57: Head up, Hand Fed Crimping

lubrication also requires some skill on the part of the operator if hand dipped. If done automatically, on a conveyor system, close heat controls are needed, plus more elaborate equipment to distribute the lubricant properly.

Solvent application poses the problem of getting rid of solvent fumes. Solvents chosen are usually non-flammable; most of them are of the non-flammable chlorinated type, such as trichloroethylene. Health restrictions in many countries generally and properly forbid the use of carbon tetrachloride. All chlorinated solvents must be vented from the area so that the operators are not exposed. The usual method with the solvent system is to dissolve the wax in the solvent, using it in a tank which has cross ventilation. The ammunition is dipped to the lead knife on the bullet and then withdrawn and the plate of loaded ammunition, bullets down, passes through a blast of hot air, which evaporates the solvent. Prior to that, however, the small drop on the nose of the bullet is wiped off. In this method, very little lubricant is wasted and the amount on the cartridge is quite evenly distributed. The lubricated cartridges go directly to packing.

Centerfire Plate Loading

As mentioned earlier, centerfire plate loading follows the same general scheme as for rimfire. It is a good method, requiring a relatively low capital investment compared to loading machines. More labor is needed however—a serious consideration where labor costs are high.

Rimless case shaking is simpler than with rimfire cases, since the shaker hole need be only a little larger than the maximum case diameter, and the use of a separate shaker plate to fit cases in the funnel plate is not necessary. Instead, a guide plate, with holes the size of the neck, is fitted over the filled case plate to orient the cases for bullet insertion.

Rimmed cases require a separate shaker plate. The cartridges fall in it head down and a cover plate is fitted, and the plates inverted on a funnel plate. The cover plate is pulled out and the cases fall neck down into funnel plate holes which fit the neck closely. A bottom plate, slid into place, holds the cartridges in when the plate is turned over, ready for powder charging.

Centerfire cases are much heavier at the head end, and fall head down in the shaker plate very easily.

Bullet shaker plates resemble rimfire shaker plates. The shape of the bullet dictates the shape of the hole in the plate. The variety of bullets is much greater and a corresponding variety of bullet plates is needed.

Powder charging is no different than for rimfire, except that the powder charge is, of course, much greater. The powder charger design corresponds to that of the rimfire charger.

Some system of powder gauging is recommended. In one system, the charged plate of cases passes under a detector which checks the cartridges row by row, the same as for rimfire. With fewer cases to check, compared to rimfire, a simpler method also works very well. In this method, a gauge plate, with a pin for each cartridge, is dropped down on the charge plate. To start with, the head of each gauging pin is well below the surface of the gauge plate. As the pin goes into the case and touches the powder charge, it is raised. The operator looks at the plate and can tell immediately whether powder charging is normal, or not. All pins should be even with the surface of the plate or slightly above or slightly below, depending on how the gauge is set. Any pin which fails to rise at all or one which stands markedly higher than the rest indicates an abnormal powder charge and an investigation immediately follows.

After gauging, the plate of charged cartridges goes to the bullet seater, where a plate of bullets is added, and the bullets seated to the proper depth. Again, seating may be for the whole plate at one time or may be row by row. Crimping may be combined with bullet seating or not, just as it is in handloading. Simultaneous crimping is perfectly feasible in row-by-row seating, but is not particularly adaptable when the entire plate is bullet-seated at the same time. Plate loading is very good for centerfire rifle bullets, but is not particularly good for lubricated pistol bullets, which gum up the plates.

Recent Developments

In the U.S., until fairly recently at least, ammunition makers have plate loaded rimfire cartridges and used loading machines for centerfire.

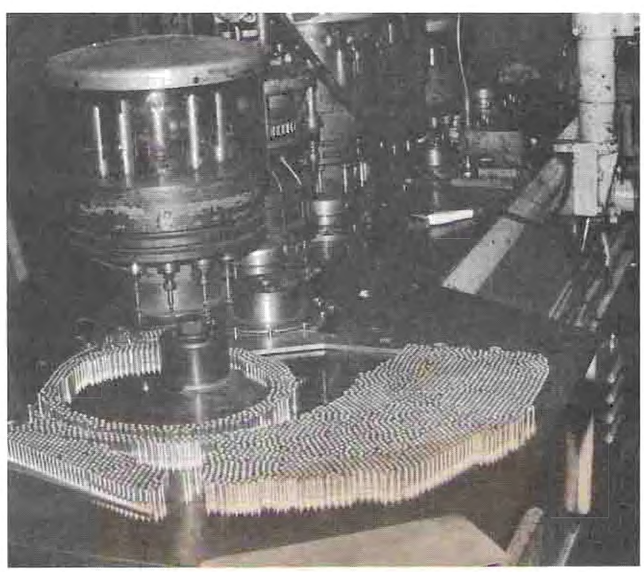


Figure 58: Manurhin Rotary Cartridge Loader

Lately, with the rising cost of labor, a loading machine that does the work of four people on a plate loading line and needs only one operator begins to look more attractive. With U.S. hourly labor costs up and adding fringe benefits, a reduction of three people adds up to a saving that could finance a fairly expensive machine.

The art of mechanizing things is such that equaling the plate loading rate of 800 to 1,000 rimfire cartridges per minute on one machine is not impossible, but such a machine would be very expensive, and probably not quite economical even yet for most cartridge makers.

The Manurhin loading machine (See Fig. 58), as used for rimfire, was planned for one operator, but the operation has, in the experience of Squires-Bingham, needed two operators, one to feed cases onto the feed dial, the other to keep the bullet feed delivering a bullet to each and every case, and to keep the machine supplied with components. It was common practice to use extra operators to man the machine during coffee breaks, rest periods, and lunch hours, in order to meet production demands.

This machine starts with a flat feed dial on which the operator using a hand orienter places the cases head down. The machine has five turrets each with twelve stations. The first turret spreads the mouth of the case. The second turret drops the powder charge in the case. The third turret gauges the powder charge level for maximum and minimum height and rejects any cases having incorrect charges. The fourth turret adds and seats the bullet. The fifth turret crimps the cartridge.

The cases feed from turret to turret by means of intermediate dials. The same general type of machine has been designed by Gulf and Western to load 600 to 1200 centerfire cartridges per minute. The Manurhin does 150 per minute, 70,000 per shift at 100% efficiency.

The plate loading line is the easiest to keep in operation. The shakers seldom need any adjustment. Powder charging, at most, needs only a change to a thicker or thinner plate as powder lots are changed. The bullet seater stays easily in adjustment. The rimfire crimper is the only machine requiring much attention, but crimping requires the same attention on a loading machine.

The most common centerfire loading machine types in the U.S. have been straight line loaders. Waterbury-Farrel and Ferracute produced many of these machines for the loading of military ammunition (See Fig. 59). They are easily adaptable to different calibers; the .30 cal. machine is readily converted to 5.56 mm, for instance. The .50 cal. machine can be likewise converted to smaller cartridges.

In this machine, the case feeds into a feed bar which carries it from station to station. The first

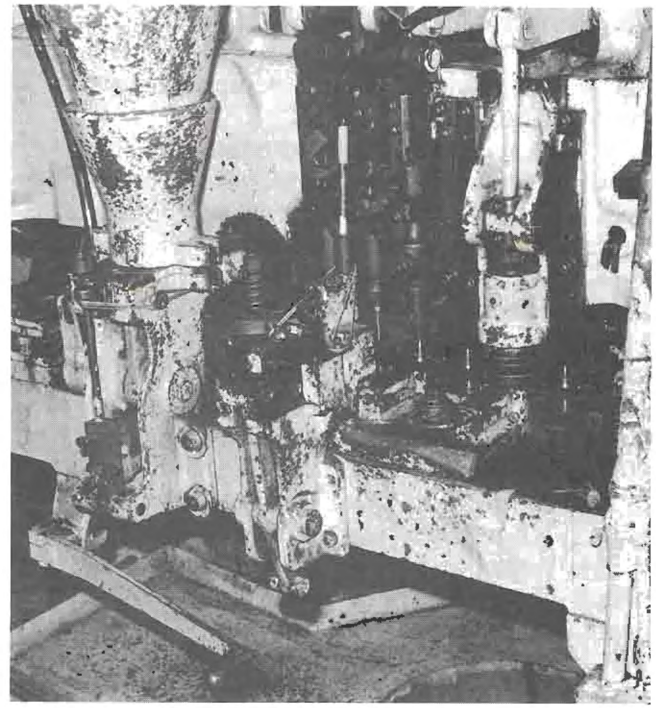


Figure 59: Straightline loader for centerfire cartridges.

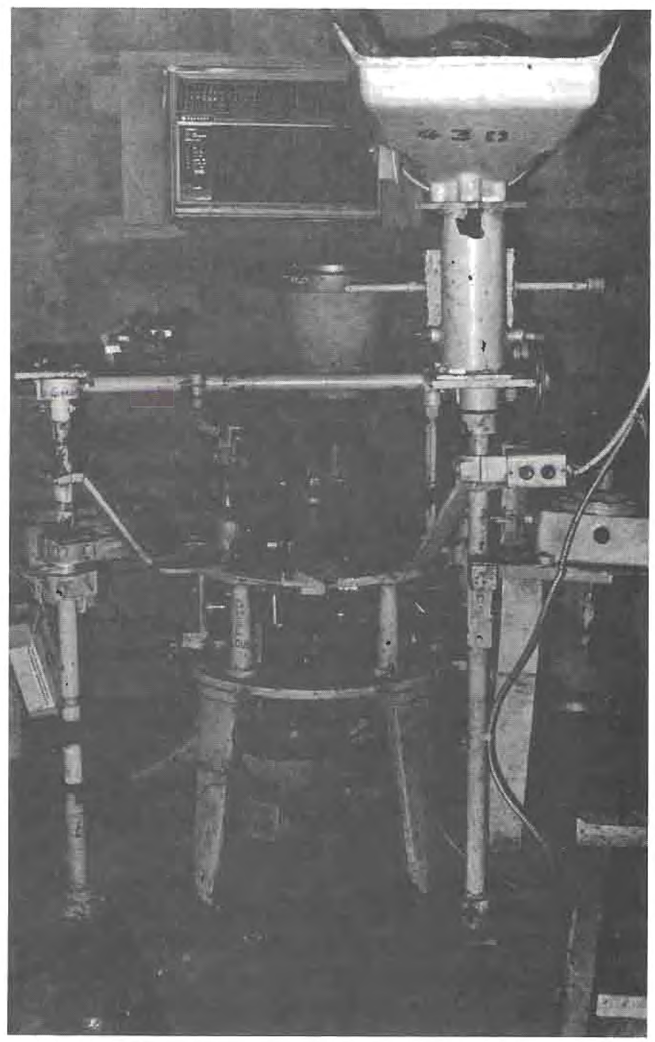


Figure 60: Rotary dial loader for pistol cartridges.

station checks the presence of the case and trues up the mouth if it has been dented in handling. If no case enters the system, the gap in the bar bypasses the other loading operations. No bullet or powder is fed to the missing case. The case moves from the first station to the second, which is powder charging. Next, the case passes the gauging station where a light, heavy, or missing powder charge causes the machine to drop the case without feeding a bullet. The following station feeds a bullet to each case presented and starts insertion. The next station seats the bullet to prescribed depth. If no bullet feeds, the case is dropped out. Passing on, the next station crimps the bullet. From here a loaded round passes on without further action or, alternatively, the round enters a rotary painting system which coats the bullet tip with an identifying color. These machines are relatively slow, loading about 40 to 45 cartridges per minute. Because of the difficulty in getting tubular grains to flow quickly through small-diameter case necks, as are found in the .222 and .223 Rem. for example, the machine may have to be slowed down to 35 per minute in order to give the powder time to drop.

For smaller cartridges, .38 Spl , .30 Carbine, and similar pistol and small rifle rounds, some rotary dial machines have been used in the States, (See Fig. 60). Many were for military loading. These machines are convertible to various calibers by changing inserts in the loading dial and altering feeds.

The expansion of reloading into the commercial field brought out some straight line loading machines, which prime the case as well as load powder and bullet. The Camdex is such a machine.

The cost of the Camdex or similar machine, tooled for one caliber, is about $5,000.00. A Manurhin machine, in 1980, was quoted at DM800,000, equal to US$400,000. The Army paid 3.5 million dollars for the development and installation of the SCAMP line, at Lake City, in 1979.

Obviously, a small, non-military operator will opt for plate loading or a simple machine like the Camdex.

As a rule, most loading machines, do not carry out any secondary operation, as, for instance, gauging. However, the SCAMP machinery does so, as does the Manurhin rotary, which accounts for part of their high cost.

Shotshell Loading

Shotshell loading, except for very special loads, is, in the factory, a machine operation. For years, shotshell loading machines in use produced from 25,000 to 30,000 shells a shift. A newer machine made by Lachaussée in Belgium does several hundred a minute, but it is a very large complicated machine, suitable for the high volume producer. Lachaussée now makes a similar rotary machine, producing about 12,000 to 15,000 shells a shift, that fits a smaller operation very nicely.

With the necessity to add one or more wads, meter the shot charge, crimp in two steps, and—with plastic shotshells—seal the crimp, shotshell loading becomes more complicated than centerfire loading. However, each step is, by itself, simple and the necessary machine is only complicated by the additional stations. Printing the load on the tube is usually done in a separate operation.

Wad pressure over the powder charge, before the advent of today's molded plastic wads, was a matter of concern in loading shotshells. It no longer has the importance that it did, but still reasonably uniform wad seating pressure should be used. More uniform breech pressures result, and more uniform velocities are apt to follow.

The older, solid wads, made of felt and paper, depended in part for their sealing effect on a tight fit in the shell case. Pressure was maintained by the wad friction after the seating ram was lifted in the machine, until the shot charge had been added, and the crimp applied. The crimp helped to maintain the pressure on the powder.

With modern plastic wads, friction is not enough to hold the wad down over a compressed powder, which quickly springs back. Before it has fully sprung back, however, the loading machine will have finished the shell, so that there is some compression between wad and crimp across the shot charge. This keeps the shell and crimp firm and tight.

Whereas with the older type of wads, seating pressures could vary breech pressure by 1,000 L.U.P (Lead Units of Pressure) or more, the plastic wads show so little change that many reloading manuals, Hercules included, no longer mention wad seating pressure at all. Even so, an initial wad seating pressure of 20 or 40 lbs., for 12-ga., is of some advantage in improving ballistic uniformity. It must be remembered that pressures should not be so high as to permanently crush the shock absorbing center of the plastic wad.

At crimping, very few loads use the old-fashioned roll crimp; rifled slug and buckshot loads being the principal ones. However, satisfactory folded crimp loading is accomplished with buckshot. The uneven top layer of buckshot makes folding slightly uneven unless the shot is nested in a filler material.

In a commercial operation, the final crimp closure after folding is accomplished by spinning. The spinner heats up by friction in operation, helping to form the most of the shotshell and making the crimp less apt to spring back and open up. A final seal at the center of the folds locks the crimp closed. Reloading does not require spinning, since the crimp is actually a re-crimp using the original folds.

As to printing on the tube, special inks are necessary for plastic tubes, as well as for paper, where printing has to be done in the presence of paraffin. This is a matter for the ink supplier to solve. Application of ink is with a small roller which rolls the message on a tube as the shell passes. The design is common to many things in the packaging industry where a label is printed on a passing object.

Packing machines are usually separated from the loading machines by an intermediate 100% inspection station. Shells pass from the loading machine to the conveyor, which passes them by the inspector. Mirrors underneath reflect the head while mirrors above reflect the crimp, so that the inspector sees the entire shell. Shells that show loading defects are picked off the machine and salvaged, if possible; otherwise, they are torn down and scrapped.

In a good operation, visual inspection defects should run below 0.2%.

The packing machine takes the shell from the inspection machine, and reverses the head on every other shell. The shells then roll down a storage ramp to the packer. In groups of five shells, they roll onto an elevator, which drops down layer by layer until 25 shells are in the accumulator in five layers. The operator places an empty carton upside-down over the accumulator and the elevator lifts the 25 shells into the carton. The operator then tips the carton off, catching the top flaps to keep the shells in place and closes the carton.

The most serious shotshell loading defect is a squib. There is very little chance of an over-charge of powder, as extra powder would not allow the shell to be crimped. A wrong powder would be detected in random shooting. A no-powder load or a missing wad or no shot charge shell would be picked off in inspection, if the missing components result in what is called a "dipped" or depressed crimp. The squib is not common due to the extreme care taken to prevent the conditions arising which could result in one. Prevention means rigid control over primer, careful selection of powder, a proper pressure level, and −40° testing. Add a continuous watch over the loading machine, plus frequent checks of powder charge, pressure and velocity checks on every machine more than once during a shift, and random shooting of shells picked off the machine. The random shooting is done by an experienced shooter, who is thoroughly familiar with good shotshell performance. Hopefully, his experience with bad performance will be minimal, but he has to know what bad performance is. Both pump and automatic shotguns are used for random shooting.

In normal practice, about one shell in every 1,000 loaded is selected for random testing. These can well be taken from visual rejects if the sampling and shooting are timely. Good performance would be a malfunction rate less than 0.025%, 1 in 4,000. Squibs should not occur more often than 1 in 500,000. Obviously, records must be kept on a cumulative basis. Unless one is loading a hundred million or more shotshells a year, daily or weekly scores will be apt to be too small to judge good quality.

This is another way of saying that every individual malfunction must be investigated at once as to cause and an immediate cure applied, if indicated.

CHAPTER IX BALLISTICS IN THE FACTORY

It is a tribute to the care and skill of the ammunition makers that a product so critical in material, dimension, and performance can be made in such vast numbers so virtually trouble free, as far as the user is concerned. On rimfire ammunition, for instance, an average misfire rate of 1 in 50,000 rounds tested is only fair performance, while a rate of 1 in 10,000 would be cause for alarm.

The factories are aware of what their running rates actually are because of the millions of rounds a year they shoot up in testing.

Dimensionally and metallurgically, the production side of the factory rides close herd on its ammunition. Functionally, the ballistic lab, or proof house, depending on whose factory, has the final say, and reports high up in the quality control hierarchy.

In order to maintain outgoing quality levels, there are daily and even hourly ballistic tests on certain attributes, weekly or monthly tests on others, some tests at random, and others as part of development programs, or new product evaluation. There is also evaluation of competitors' products.

Many of the U.S. firearms and ammunition makers have joined together in an association, the Small Arms and Ammunition Manufacturers Institute, called more simply, SAAMI. Its principal technical function is to work toward membership-wide, at least, practices and standards for ballistic tests, and dimensional standards to assure that a cartridge of a given caliber will surely chamber in all standard firearms made for that caliber. Also, to assure that the normal range of working pressures of the ammunition is less than the proof pressures to which the firearm has been tested.

SAAMI also provides guidelines for velocities, so that the user can change loads as well as brands and know that his sight settings won't be affected by unexpected differences in velocities.

Another guideline is that of primer sensitivity. Primers must fire reliably under a normal firing pin blow, but must not be so sensitive as to fire accidentally in normal handling and loading.

Equipment standards and test methods are recommended, and within itself SAAMI provides test ammunition, standardized as to pressures and velocities, for comparison testing. Most ballistic testing for pressure and velocity is against these or similar standards.

The head man in the ballistic lab is a man of great influence, and rightly so. In most cases, he arrived at his job by coming up through the ranks, there being no outside training school for would-be company ballisticians. Long exposure to the job, a wide and deep knowledge of the cartridge and its care and feeding make him a key figure.

In their day, some ballisticians like the late Murton Robinson of Winchester, have won national renown in their field. Robinson is often credited with having brought into use one of the forensic ballistician's favorite tools for checking fired bullets against the gun in which they might have been fired, the comparison microscope.

Murt Robinson was an authoritative expert witness on things ballistic, but his main contributions to the overall picture were a long memory, a sharp eye, and a nose that instinctively smelled trouble before it got out of hand.

On one occasion, his sharp eye saved the company a potential loss in what was then the largest personal injury suit the company had entertained, and it had nothing to do with ballistics.

Out in California, a man walking past a shooting gallery in a well known amusement park, was hit in the eye by something and as a result lost the eye. He sued the gallery operator, the gallery owner, the amusement park, the ammunition distributor, and Winchester for $699,000. That amount may be peanuts, today, but it was a pile of money then.

When pre-trial depositions were taken in the East, it was quite obvious that the gallery owner and operator and the park were going to hang the blame on the ammunition maker; where it didn't necessarily belong.

What hit the plaintiff's eye was not known; the evidence was lost in the hospital.

With a badly pitted back stop or target, pieces of steel or rust are sometimes kicked back. Further, the gallery bullet, even though designed to break up upon hitting a solid surface, may not disintegrate completely on poorly maintained gallery plates. There was also no proof that whatever hit the eye actually came from the gallery.

The case came to trial. The operator first swore

the gallery had never used anything but Winchester cartridges. The plaintiff's lawyer introduced two photographs, Exhibit A, taken from the counter end of the gallery toward the targets, and Exhibit B, taken from the target area looking toward the counter.

Robinson, sitting next to the defense attorney, glanced at the two exhibits as they were passed, narrowed his gaze on Exhibit B, brought out his pocket magnifying glass, looked again and whispered to the lawyer.

On cross examination, defense counsel dropped the bomb.

"You have never used anything but Winchester ammunition?"

"No."

"And Exhibit B is a photograph of your gallery?"

"Yes."

"When was it taken?"

"Right after the accident."

"Is the gallery the same as it was at the time of the accident?"

"Yes."

"Then please explain to the court why, if you have used nothing but Winchester ammunition, there is a Remington ammunition case under the counter."

Which blew the case out of court.

As with most successful continuous mass production operations, a sort of rhythm develops in the ammunition manufacturing process when it's going well. Machines perform as expected, material flows along within tolerances, and the product quality is uniformly high. Even so, the ballistic lab keeps a constant eye for trouble brewing. One simple malfunction, among the hundreds or thousands of test rounds fired daily, may be the harbinger of a whole rash of similar malfunctions to come, or it might not be especially important. The alert ballistician, quickly, and to a degree intuitively, assesses the situation and immediately calls the turn as to whether to blow the whistle, stop production and call for correction, or whether the malfunction was random and of small import.

At Western, Vince Transue was Robinson's counterpart, as well as his contemporary, and more than a little of the credit for the company's high quality levels was due to his feel for the situation.

Back to the lab. Routine daily, and even hourly, tests are made of pressure, velocity, powder charge weight, bullet pull, functioning, accuracy, and primer sensitivity.

Velocity Measurements

In today's world of electronics, tidy, new small chronographs, light screens, and instant readings, the LeBoulengé chronograph is something only the old timers will remember. Velocities, however, were being measured indirectly long before the LeBoulengé.

Not the first to give thought, but probably the first to bring a combination of theory, practice, and an inquiring mind to things ballistic, was an Englishman named Robins. In 1742, he published his *New Principles of Gunnery*, making him the great great grandfather of modern ballistics. Among his contrivances was an instrument called the Ballistic Pendulum. With the pendulum, velocities, from muzzle, up to any reasonable range, could be determined. Once velocities of various projectiles could be measured, the number of avenues that could be followed was numerous. The principal area of exploration was with cannon, both naval and field pieces. The same principles, however, could be applied to small arms. Robins' book, translated into German and enlarged by Eules, was retranslated back to English by Hugh Brown in 1777 and it was partly the basis for a series of experiments at Woolwich in England by Dr. Hutton. A reading of the courses of experiments sounds much like current experimentation:

1. The velocities from various barrel lengths with equal charges of powder and balls of equal weight.
2. Velocities with different charges of powder.
3. Maximum velocities vs barrel length.
4. Effect of different weight cannon.
5. Penetration into wood blocks.
6. Velocities at different ranges.
7. Determination of velocity changes vs range, and of the effect of air resistance.
8. The effects of wads, of charge compression, of vent location, and of fit of ball to bore.

The principle of the pendulum in measuring velocities is not complicated. A heavy wood block was supported from a long wire or rod so that it could swing freely. A ball fired into the block would cause the block to swing backwards and upwards in an arc, like a pendulum.

The angle of maximum backward swing was measured. Obviously, the height to which the block would swing would be dependent on the velocity which the impact of the cannon ball gave it. Neglecting the small amount of air friction, the pendulum, swinging back, would reach the same velocity at which it started out. This would be the same velocity the block would reach if it fell vertically the same distance it reached at the height of its swing.

Now, according to Sir Isaac Newton, whose word we have no cause to doubt, even though he was struck on the head by an apple, a certain rule applies: Mass times Velocity = mass times velocity.

Pitting the block times its velocity against the cannon ball times its velocity, the two would balance each other, except for one small addition. When the cannon ball was fired into the block, it added its weight to the block, so that the corrected

equation should read:

$$B \times V_{Ball} = (P + B) \times V_{Pendulum}$$

Cannon Ball wt. × its Velocity = (Block wt. + Ball wt.) × their Velocity

Again, going back to Sir Isaac, the velocity the ball and block together would attain in falling from their maximum height of swing would be: $V_p = \sqrt{2gS}$, where g is the acceleration due to gravity, 32.2 ft. per second per second, and S is the height of fall.

Finally then, the velocity of the cannon ball would be computed thus: $V_B = [(P + B)\,V_p] \div B$

The pendulum weight selected depended on the weight and velocity of the projectile. The heaviest weight that Robins used was about 90 lbs. He was working with small caliber guns. The heaviest used at Woolwich weighted 7,400 lbs. Cannon ball velocities as high as 2,000 f.p.s. were measured.

A 7,400 lb., 15-foot pendulum hit by a 24-lb. cannon ball traveling 2,000 f.p.s. will swing through an arc of 16.9°, raising itself .65 feet.

One may be led to the thought that velocity might also be computed if the cannon or firearm were itself suspended. The resulting pendulum will recoil, to the rear and upwards a measurable amount. But the resulting computed velocity would be too high.

The answer is that everything that leaves the muzzle at the time of firing adds to recoil. This includes the powder, and in a shotgun, the wad. Subtracting the weight of the wad will help. The powder, however, is another matter. Powder gas, being elastic and under pressure, expands faster than the shot moves, so that its own particular "MV" adds more in proportion than the MV of the shot. It is convenient, when computing potential recoil of a firearm, to multiply the powder weight by a factor of 1.5 to 2, depending on powder and muzzle pressures, and add this increased weight to the shot weight, and wad weight. When so doing, the resulting computed recoil of a gun follows closely the actual recoil as measured by the same gun and load in a pendulum. Again, however, it must be remembered that this does not lead to a very accurate computation of shot velocity.

Velocity, for many years, was measured using a cumbersome instrument known as the Le Boulengé chronograph. In U.S. military practice this measurement was usually made over a total distance of either 103- or 153 ft., depending on the general range into which the velocity was expected to fall. The bullet, leaving the muzzle, cut a wire 3 ft. down range, which broke an electromagnetic circuit and allowed a steel rod to drop. On striking a target, the bullet activated another circuit that caused a small knife to make a nick in the falling rod. The rod, in the meantime, was unemotionally following the law of gravity and falling freely, so that the location of the nick showed how far the rod had fallen. The distance fallen could be translated into time of flight and thence into a velocity, which would be the average velocity over the distance of flight. Again, in military practice, this came out to be either 53 ft. (3 ft. for the distance to the start wire plus half the hundred-foot instrumental spacing) or 78 ft. Civilian ammunition makers using Le Boulengé velocity measuring equipment usually used a 120-ft. instrumental spacing regardless of expected velocity.

Under ideal conditions, a Le Boulengé chronograph was capable of measuring time intervals with as little as .0001-second error, but the error could, and did, become much greater in normal operation.

As can be seen, muzzle velocity, or any other velocity, cannot be instantaneously measured. There has to be a time of flight measurement over some distance, no matter how small.

With modern electronic instruments, extremely small time increments can be measured so that Le Boulengé-like distances are no longer necessary. Instrumental spacing as short as one foot can be used, but a chronograph that measures down to only 0.00001 sec.—as many of them do—won't give very good definition to the results. At velocity levels around 3000 f.p.s., for example, flight times of .00033- and .00034 sec., over 1-ft. instrumental spacing, correspond to velocities of 3030 f.p.s. and 2941 f.p.s., values separated by 89 f.p.s. Increasing the instrumental spacing to 10 ft. (and multiplying the time by 10 for purposes of the example) would introduce 11 time increments between .00330- and .00340 sec., and make possible velocity values that are separated by only eight or nine f.p.s.

There have been several methods of making and breaking circuits in the time-interval counter (chronograph). Wires at muzzle and target distance give some error, in that the wire stretches before it breaks. Printed circuits on paper have the same fault, but those on glass do break cleanly and quickly. Broken glass, however, is messy. The coil disjunctor, started and stopped by the change of inductance which occurs when the bullet or shot charge passes through the central hole in the coil, was in use for many years and worked well. Today's photoelectric screens, which uses the momentary passage of a bullet between a light source and a photoelectric cell to trigger the instrument, seems to be the best all-around answer. The newer screens on the market today are reasonably priced as well as reliable.

There does seem to be a certain predilection on the part of velocity shooters to misalign the barrel, so as to shoot a hole through either the light source or the photo-electric circuit. The latter, being the one of most frequent choice, creates an incurable defect in the equipment. It is best, therefore, to place a cut-out steel plate in front of each screen

to protect it. Then, to protect the shooter from the splash-back of a frustrated bullet, the plate should be faced with two inches or so of good solid replaceable hardwood.

During the last 50 years, as various means of measuring velocity have come along, they have been related back to the longer range velocities of the Le Boulengé era, so that a reasonable continuity of muzzle velocities has been maintained.

When the coil disjunctor came into use, its coils were placed in line with the muzzle wire and target plate of the Boulengé and each shot gave readings on both systems. Likewise, when photo-electric screens came into use, their use together with the disjunctor allowed a direct comparison between readings.

The coil disjunctor was a clever means for starting and stopping a chronograph developed at Remington Arms Co. Primarily useful when charges of shot are involved, it is based on changing inductance as a metallic material passes through the hole in the center of the coil. The coil works through an amplifier, which uses the changing inductance to feed a start or stop signal to the chronograph.

The final result is that a 3-$1\frac{1}{8}$-$7\frac{1}{2}$ trap load today, for instance, has the same actual velocity level as it had 40 years ago, when the Boulengé was still in use, although time intervals are measured and corresponding velocities are read entirely differently.

Among the various means to measure short intervals of time which came and went at Western was a clever instrument worked up by the research people at East Alton, utilizing a galvanometer. In the circuit, breaking the muzzle wire allowed current to flow into the galvanometer from a condenser, carefully insulated and temperature controlled. At the target plate a short distance away, the bullet broke the circuit, stopping the condenser's discharge. The coil in the galvanometer continued its swing until it had used up the energy delivered by the condenser. As might be expected, the next problem was one of calibration.

The answer was to set up a synchronous motor with a flywheel having a knife set into its outer circumference, so that it cut a circle in the air with each revolution and moved at a predictable rate. A frame, conforming to an arc of the radial path followed by the knife blade, had two wires stretched across it, one corresponding to muzzle wire, the other to target wire. This frame could be dropped so that the knife blade cut first one wire, then the other in a known interval of time, which corresponded to a certain swing of the galvanometer, giving a basic calibration. This instrument worked, but was clumsy and never got into the league with the skyscreen and counter chronograph.

At Aberdeen Proving Ground, another quite workable device, also based on a synchronous motor, was developed. The motor rotated a drum, around whose surface a sensitive paper was wrapped. When the shot broke the muzzle wire, a spark passed from a point near the drum through the paper, leaving a mark. Likewise, when the bullet hit the target, another mark was left on the paper. Since the drum was rotating at a constant rate, the distance between the two marks was a measure of the passage of time from muzzle to target. The disadvantage of this device was that it took time to remove the sensitive paper, measure the distance between the marks, and compute the velocity. Then more time was consumed in putting a new paper on the drum. Except for the inconvenience in getting the answer, the system was good and quite accurate.

Perhaps one of the most ingenious systems was one developed by Ed Florman at Western. Using an oscilloscope and impressing on it the sine wave of the local alternating current, the result was a circle on the tube. By varying voltage, the size of the circle was changed. The voltage was varied by a spring loaded potentiometer moving at a steady rate. This changed the circle to a spiral.

Next, he put an oscillator in the circuit, which broke the spiral up into dots, each dot representing 0.0001 sec.

A series of very light metallic screens were then set up along the bullet's trajectory, each screen being connected to the oscilloscope. When the bullet passed through a screen, a dot was left out of the spiral.

All that remained was to take a picture of the retained image on the oscilloscope, enlarge it, and count the dots between each missing dot. From this, the time of flight between each screen was measured and the corresponding velocity computed.

Time consuming, but the only way, up to that time, of getting a series of consecutive velocities from a single shot.

Today's chronographs compute the velocity and present the figure immediately, and they also can store up several readings and give the average on call, plus the standard deviation of the velocities, if desired. In general, velocity measuring equipment has tended to become smaller, more convenient to handle, much more reliable, and, best of all, less expensive than the older vacuum-tube chronographs. The screens, too, are more compact and reliable.

It will be found on some loads and calibers that the muzzle blast will give a false reading if the screens are too close. The cure is either to move the screens farther away, or to place an expendable sheet of stout cardboard just in front of the muzzle screen to deflect the gas.

By placing the first screen 10 ft. from the muzzle, and the second 10 ft. further on, one will essentially

be recording the average velocity at 15 ft., over a 10-ft. interval. For high velocity cartridges, this spacing is usually okay.

For rimfire, the screens can be moved in to 5 ft. and 15 ft., recording velocities at 10 ft. over 10 ft., or, if one wants to approach muzzle velocities, a spacing of 5 and 5 will give a reading at 7′ ft. Close, but still not muzzle. SAAMI standard is at 15 ft. over a 20 ft. interval between screens.

The 5 and 5 spacing works well with shotshells. The shot charge presents a problem in measurement for the purist, however, as the two ends of the shot charge are moving at different velocities, due in part of the effect of the choke.

In a 12-ga. barrel, bore size is a nominal 0.729″, while full choke diameter is 0.693″. In reducing the diameter of the shot charge at the choke, the shot column is lengthened. This has the effect of speeding up the leading end of the shot charge, so that it is moving at an appreciably higher velocity. The faster shot get to the target first, providing they haven't been mutilated and flattened. This velocity difference is one cause of "shot stringing" at hunting ranges. At the other end mutilated shot lag behind, lengthening the string.

For instance, suppose the length of the shot string at 40 yds. is 6 ft—not an unusual length. The string is the distance between the first shot to reach 40 yds. and the last shot to reach the same distance. If the leading shot are from a 12-ga. $3\frac{3}{4}$-$1\frac{1}{4}$ oz. of No. 6 shot load, their velocity at 40 yds. will be about 816 f.p.s. and their time of flight will have been .12 seconds. The last shot, in the string, will, during the same 0.12 seconds, have traveled 6 ft. less or 114 ft. instead of 120, and its 40-yd. velocity will be about 780 f.p.s. The difference in velocity was even greater at the muzzle, since the higher velocity shot loses its initial velocity more rapidly.

Which gets us back to the problem of measuring shotshell velocities. The foregoing simply indicates that the problem is about as complex as one wants to make it. From a pragmatic point of view, the real name of the game is uniformity, once a desired performance level based on shot size, charge weight, and killing power on the intended game at the intended range has been reached by field experience. Routine velocity measurement as a control is to assure both maker and user that the load furnished is as specified.

Pressure Measurements

While the methods of measuring velocity were tried and in use as early as 1742, as remarked earlier, pressure measurements were more difficult to achieve, and it was not until General Rodman, a man of many ideas, set his mind to the problem that real progress was made. In the late 1850's, Rodman devised what is essentially today's "crusher" system of measurement. His experiments went further. With the pressure gauge as a tool, he made great changes in the form and size of powder grains, principally for various sizes of cannon powder. Thus was developed the principle of "progressive burning" in powder, blackpowder then, but applied to smokeless powder later.

The pressure gauge to this day depends upon the movement of some element in the system under the influence of pressure. In the case of the copper or lead crusher, a piston, driven by the pressure developed in the chamber, moves against a special cylinder of copper or lead. Depending on the pressure, the length of the cylinder is shortened by varying amounts. The amount of shortening is, therefore, an indication of the pressure level.

Crushers are calibrated in a testing machine under various loads and the corresponding deformation is measured. Results are interpolated and expanded into a "Tarage Table." Comparing the shortened length of a crusher against the final lengths shown in the table leads to a pressure reading (See Table 7).

The pressure reading given by the crusher is not the actual peak chamber pressure. At best, it might be as much as 80 or 85% of the actual.

The flow of copper under pressure is slower than the changes in pressure which cause the flow, and the peak pressure is only momentary, leading to a low pressure reading. On the other hand, the piston is given a velocity and a corresponding energy, depending on its weight, which would tend to increase the amount of crush. So it's one factor against the other and the two factors do not offset each other exactly. Only by chance alone, and at times unknown, would the actual pressure and the crusher pressure coincide. Hence, a relatively new convention in stating pressure results: Copper Units of Pressure (C.U.P.).

For years it has been convenient and a common practice to record pressure results in terms of pounds per square inch (p.s.i.) or other normal units of pressure. The more modern practice, bending toward the truth, calls the results C.U.P., or "Lead Units of Pressure," L.U.P., depending on the crusher used.

Because these transient pressure phenomena are even less fleeting than a rabbit's love affair, no such thing as an absolute pressure in firing is ever measured, and all pressures measured under the same condition are at best only relative.

Relative pressures themselves aren't so bad. The purpose of pressure measurements are two-fold. Uniformity in pressure is indicative of quality, leading to uniform performance, which is one reason. The other is one of safety.

Working pressures in must be kept surely less than proof pressures, in the interests of safety. The normal variation in pressure from shot to shot in

Table 7

Olin Corporation .146 inch × .400 inch Copper Crusher Cylinders for use with .206 piston, area 1/30 square inch. Pressure given in hundreds of pounds

Final Length	Press	Final Length	Press	Final Length	Press	Final Length	Press	Final Length	Press
.3945	48.	.3795	102.	.3645	143.	.3495	179.	.3345	214.
.3940	50.	.3790	103.	.3640	145.	.3490	180.	.3340	216.
.3935	53.	.3785	105.	.3635	146.	.3485	181.	.3335	217.
.3930	55.	.3780	106.	.3630	147.	.3480	182.	.3330	218.
.3925	58.	.3775	108.	.3625	149.	.3475	184.	.3325	219.
.3920	60.	.3770	109.	.3620	150.	.3470	185.	.3320	220.
.3915	62.	.3765	110.	.3615	151.	.3465	186.	.3315	221.
.3910	64.	.3760	112.	.3610	152.	.3460	187.	.3310	222.
.3905	66.	.3755	113.	.3605	153.	.3455	188.	.3305	223.
.3900	68.	.3750	115.	.3600	155.	.3450	190.	.3300	224.
.3895	69.	.3745	116.	.3595	156.	.3445	191.	.3295	226.
.3890	71.	.3740	117.	.3590	157.	.3440	192.	.3290	227.
.3885	73.	.3735	119.	.3585	158.	.3435	193.	.3285	228.
.3880	75.	.3730	120.	.3580	159.	.3430	194.	.3280	229.
.3875	77.	.3725	121.	.3575	160.	.3425	196.	.3275	230.
.3870	78.	.3720	123.	.3570	162.	.3420	197.	.3270	231.
.3865	80.	.3715	124.	.3565	163.	.3415	198.	.3265	232.
.3860	81.	.3710	125.	.3560	164.	.3410	199.	.3260	233.
.3855	83.	.3705	127.	.3555	165.	.3405	200.	.3255	234.
.3850	84.	.3700	128.	.3550	166.	.3400	202.	.3250	236.
.3845	86.	.3695	130.	.3545	167.	.3395	203.	.3245	237.
.3840	87.	.3690	131.	.3540	168.	.3390	204.	.3240	238.
.3835	89.	.3685	132.	.3535	170.	.3385	205.	.3235	239.
.3830	90.	.3680	134.	.3530	171.	.3380	206.	.3230	240.
.3825	92.	.3675	135.	.3525	172.	.3375	208.	.3225	241.
.3820	93.	.3670	136.	.3520	173.	.3370	209.	.3220	242.
.3815	95.	.3665	138.	.3515	174.	.3365	210.	.3215	243.
.3810	97.	.3660	139.	.3510	175.	.3360	211.	.3210	245.
.3805	98.	.3655	140.	.3505	177.	.3355	212.	.3205	246.
.3800	100.	.3650	142.	.3500	178.	.3350	213.	.3200	247.

Typical Tarage Table for Copper Crushers,
Final length in inches, Initial length, 0.400 inches

both working and proof pressures must not cause an overlap between the two. The usual proof convention is that proof pressures on the average should be about 150% of working pressure averages. As long as these relationships are maintained, the fact that pressure results are only relative and not absolute is not important.

An earlier British method placed a crusher in the breech mechanism, so that the head of the cartridge case worked against it in firing. Since the brass case expanded in firing, increasing the friction between case and chamber, the case was anointed before firing with an exotic product, referred to in the literature of the time as "Rangoon Oil." Presumably, a shortage of rangoons, or whatever, retired the method, at least in the U.S.

More modern practice locates a gas piston in or near the chamber area in the barrel wall. A yoke on the outside of the barrel over the piston provides an anvil, against which the crusher is compressed by the piston.

The piston is located at the mouth of the chamber for rimfire cartridges, nearly so for most pistol and revolver cartridges, and an inch ahead of the breech for centerfire rifle cartridges. U.S. piston diameters are standard at 0.146″, 0.206″, and 0.225.″

Rimfire uses the 0.146″ piston with both copper and lead crushers, depending on the pressure level.

Shotshells take 0.225″ diameter, while rifle and pistol use all three, but at different pressure levels.

Crushers come in two diameters, 0.146″ and 0.225″, and two lengths, 0.400″ and 0.500″. Lead crushers come in one size only, 0.325″ diameter and 0.500″ long. Table 8, indicates various use combinations.

Copper crushers are made from electrolytic copper, 99.9% pure, containing a small amount of silver, hard drawn to a diameter of 0.1465″–0.147″ for the 0.146″ crusher, and 0.2255″–0.226″ for the 0.225″ crusher.

After being cut into cylinders 0.15″ over finished length, the crushers are tumbled in garnet dust to remove burrs. They are then to be annealed for

Table 8

CRUSHERS AND PISTONS

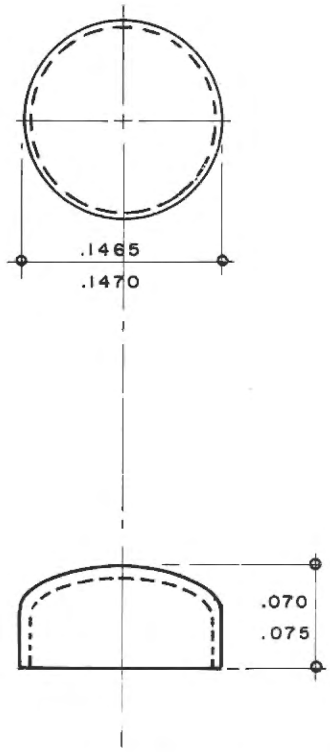
Crusher	Dia.	Length	Piston Dia.	Pressure	Use
Copper	.146	.400	.146	Below 35,000	Centerfire
"	"	"	.206	Below 24,000	"
"	.225	.500	.146	Over 35,000	"
"	"	"	.206	24,000 to 55,000	"
"	"	.400	.206	Over 55,000	"
"	.146	.400	.146	Above 15,000	Rimfire
Lead	.325	.500	.146	Below 15,000	"
"	.325	.500	.225	All tests	Shotshell, except proof
Copper	.225	.500	.225	—	Shotshell proof

one hour at 538–540° in a nitre bath (1 part KNO_3 to 2 parts $NaNO_3$), dipped in sulfuric acid to remove scale, then washed thoroughly. Both ends of each crusher are then sheared square with the cylinder's axis to a final length of 0.400 ± 0.0005″, or 0.500 ± 0.0005″ for the appropriate diameter. All should be gauged for length with a micrometer. Over-length crushers may be adjusted for length, but the end must be kept square.

Lead crushers are made from pure lead, extruded to 0.325 ± 0.001″ diameter. After being cut to a length 0.020″ oversize, they are sheared to a final length of 0.500 ± 0.0005″, and gauged for length. Lead crushers should not be deburred by tumbling.

To spare wear and tear on the piston, a pressure gun uses replaceable gas checks that are seated at the bottom of the piston hole, just clear of the chamber or bore. To make use of gas checks possible, pressure pistons are normally shorter than the thickness of the barrel wall, at the piston hole, by the height of a gas check plus 0.002″ to

0.005″ (see Fig. 61). In use, the gas check is placed in the piston hole, cup side down—the cup being filled with a special wax—and pushed down ahead of the piston until the head of the piston is flush with the barrel. A new check is used with each shot, the used cup being pushed into the fired case prior to its extraction.



GILDING METAL 95 % COPPER, 5% ZINC
GRAIN SIZE .015 - .030 mm
THICKNESS .0095 - .0010

Figure 61: Pressure Gun Gas Check—For use with 0.146″ Diameter Piston

The gas check is filled with wax of the following composition:

Beeswax	134 g
Paraffin	6 g
Vaseline	6 g
Castor Oil	14 g
Red Lead	72 g
Iron Oxide	24 g
Rosin	5% by volume

Melt, stir while cooling, roll into convenient sticks. Fill the gas check by scraping it with wax stick. Use of wax to fill gas checks is not practiced by all ballistics labs. The purpose of the wax is to fill up the vacant space in the gas check to make the pressure check more closely duplicate actual chamber space in normal firing.

Now, we come to the question of whether or not to pierce the case at the piston hole location. In the case of rimfire and pistol and revolver cartridges, the problem does not exist, since the piston hole is not in the case area in the chamber. But it must be considered in testing shotshells and rifle cartridges.

Again, there are several factors to be considered. Making a hole in the case, whose function is to obturate and seal off any gas leakage, would seem to be counter-productive. Against this is the disruptive effect the intervening paper or brass case has on the powder gas acting on the piston. The matter is easily solved with the shotshell. A sharp punch is pushed down the piston hole puncturing the case in exactly the right spot. At the relatively low pressure of the shotshell and with the flexibility of the paper or plastic tube, gas leakage is not a problem. Moreover, paper or plastic shears rather easily against the sharp edge of the piston hole and pressures are not greatly affected. If the case is not punched, there is a difference in tube shear strength from one type of shotshell to another, so it's good to establish as uniform a set of test conditions as possible by piercing.

With centerfire rifle, where pressures are high, the sidewall is much stronger and more pressure build-up is needed before case rupture occurs, piercing a hole in the case would seem to be proper. However, it isn't practical to run a punch down the piston hole, and the case must be drilled before insertion into the chamber. The drilled case must be handled carefully so as not to spill any powder and be inserted so that drilled hole and piston hole coincide.

The expedient thing seems to be that, for routine checking, unpierced cases, particularly when checked against standards, give satisfactory comparative results. In fact, there is generally very little difference in readings between pierced and unpierced cases.

Pressure test shooting is to a degree an art. For uniform results, all actions in handling the ammunition, inserting piston, setting the crusher, seating the gas check, if any, inserting the cartridge, and closing the breech must be done uniformly. Prior to shooting, the ammunition must be conditioned for at least two hours at a standard temperature and humidity (70°F and 50% relative humidity are U.S. standard).

One of the keys to uniformity is the positioning of powder in the case. By setting the cartridge head down in a loading block, picking it up carefully, rotating it slowly 360°, end-over-end, and then carefully and slowly inserting it in the chamber and closing the action gently with a minimum of disturbance, the powder ends up uniformly in the primer end of the case. Pressure readings are usually lower if the powder is positioned at the bullet end, higher at the primer.

Two fouling shots should precede any pressure test. Prior to insertion, the piston is dipped in SAE

30-weight oil, allowed to drain and the drop of oil gathering at the end wiped off.

The piston must move freely up and down in the hole.

Rate of fire should be slow enough that the barrel doesn't get hot. With centerfire, air may be used to cool the barrel, so that shooting is not slowed up.

All of the above concerning pistons, gas checks, piercing and other items having to do with pressure testing can be done away with if the use of the piezo-electric transducer is adopted (See Fig. 62). This type of gauge makes use of the fact that, when certain crystals, quartz for example, are compressed, they develop an electrostatic charge directly proportional to the pressure applied. The beauty of the piezo-electric type of gauge is that it acts instantly and the varying pressure developed during firing can be monitored from first flash of the primer to zero pressure again sometime after the bullet exits the muzzle. Hooked up to an oscilloscope with suitable time base, a complete pressure curve can be produced. The gage is set into the chamber or bore wall, does not interfere with the case and is good for many shots.

As might be expected, though, in this garden of perfection a small weed grows. How does one calibrate the instrument, readings again being relative?

In this case, one method of calibration is done in reverse. The piezo gauge is loaded to the desired level and the pressure is suddenly released, giving a reverse reading. Routine calibration is therefore a little more complicated than the ballistic lab is normally ready to undertake. It is normal practice to return the gauge to its maker for occasional recalibration. Again, checking pressure readings against ammunition standards will quickly show whether or not the instrument is giving normal readings.

As an adjunct to the piezo gauge, one has a choice of instruments to handle its output, so as to present the data in an easily digestible form. As mentioned earlier, the most spectacular item is the oscilloscope which can present the complete pressure curve, holding the image on the face of the tube for direct measurement, or for photographing for record. Other instruments record peak pressure, giving direct readings in whatever units are desired (See Fig. 63).

At the same time, the area under the curve may be integrated to give total force. Barrel time, from hammer fall to bullet exit may be measured, also.

In spite of Pascal's Law, which says that fluid pressure in a vessel is transmitted equally in all directions, the piezo system says that, under the rapidly changing situation inside the chamber and barrel, law and order according to Pascal don't always prevail.

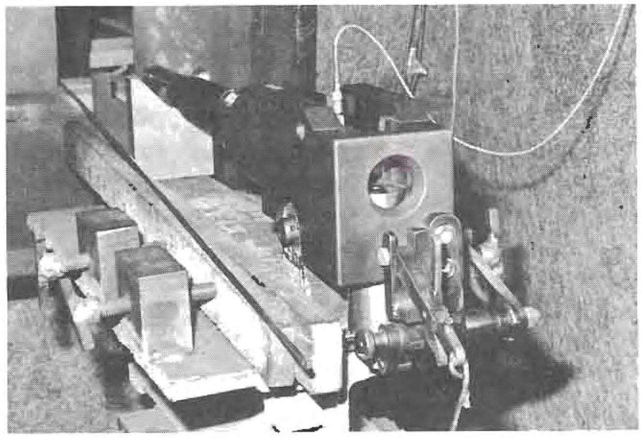


Figure 62: Universal Receiver Set Up for Piezo-Electric Pressure Measurement

Back quite a few years ago, the American Rifleman began getting a few letters from NRA members, complaining that the .30 cal. ammunition they had been getting through the Director of Civilian Marksmanship was apparently making rings in the chambers, or rather in the chamber necks, of their rifles.

Examination of fired cases sent in did show a circular ring mark around the neck just back of where the bullet had been seated. The complainants universally said that their chambers had been unblemished when received and that they had not done anything to the chambers themselves.

Samples of the ammunition were fired, giving normal pressure readings, and, after these firings, rings looking like tool marks were found in the chambers.

A test barrel was made with a piezo transducer located in the chamber at the precise point where the rings were occurring. The oscilloscope showed a normal pressure rise, but near the peak point the smooth curve broke up into a saw-tooth pattern with the peaks rising clear off the record, indicating extremely high, very momentary pressures. The piezo in the normal place in the chamber at the same time showed nothing unusual.

The most probable cause, not easily explainable from ordinary experience, was that some sort of

Figure 63: Instrumentation for Piezo-Electric Pressure Measurement

resonant effect was taking place. A pressure wave, coming from the rear of the case, was meeting an earlier wave which had been reflected back from the base of the bullet, and, when the two waves met head on, it was a little like the irresistible force meeting an immovable object—something had to give—and the resultant force, possibly a highly localized detonation, created the ring.

Various other powders with charges giving the same muzzle velocity were tried under the same conditions and no rings occurred. After considerable study, it was concluded that the ignition and burning characteristics of the specific powder involved created the rare happenstance.

Some work has been done on measuring pressures with strain gauges. Increased strain on a special wire, stretched between two circumferential points around the chamber, caused by the expansion of the chamber under pressure, changes the resistance in the wire. With the wire in a circuit including an oscilloscope, the change in resistance can be converted into a curve representing pressure change. As usual, there immediately arises the question of calibration, and it would be handled in the usual way—comparison against ammunition standards. This system is too finicky and too awkward to be of good daily use in production.

Standards

"Standard Ammunition" is ammunition, the pressure and velocity levels of which have been assessed in a number of test barrels in several ballistic laboratories, and the results averaged. It is a boon to the ammunition maker, to whom it gives some means of assurance of producing his product to safe velocity and pressure levels comparable to industry practice.

Commercially, standards are furnished as loaded ammunition, while the U.S. military furnishes its ammunition suppliers with standard cases, bullets and powder as separate components which are loaded by the user.

The standards are used to establish correction factors for a particular set-up of test equipment.

For example, suppose a standard lot of ammunition is assessed and gives average velocities of 3148 f.p.s., average pressures of 51,300 C.U.P.

The ammunition maker fires a sample of this ammunition in his velocity barrel and finds the velocity averages 3196 f.p.s., 48 f.p.s. higher than the assessed value. A correction factor of minus 48 f.p.s. is then applied to all tests of the maker's own ammunition when fired in that barrel. If a routine velocity test shows an average velocity of 3122 f.p.s., the corrected velocity would be 3122 f.p.s., minus 48, or 3074 f.p.s.

Similarly, a pressure barrel tested with the standards and giving an average pressure of 50,000 C.U.P. would have a correction factor of +1,300 C.U.P. In any test of other cartridges in the same barrel, 1,300 C.U.P. must be added to the average pressure reading to give the corrected pressure.

Standards, being costly to produce, assess, and distribute, are used sparingly, but always when there is reason to question a barrel's performance.

Test barrels are frequently checked against standards to make sure that barrel wear and equipment performance haven't changed the amount of correction needed. In any critical test, it is customary to fire standards before, after, or alternately with the ammunition being tested, alternately being preferred.

Accuracy

Accuracy is a matter of considerable importance in both centerfire and rimfire ammunition testing. For centerfire ammunition the equipment of choice is still generally the time-honored Mann barrel and machine rest. The barrel is a very heavy one with two concentric bearing surfaces located near muzzle and breech. These two bearings ride in a long V trough, in which the barrel can slide back and forth. The action is frequently a bolt type, but without stock. The V block is mounted on a heavy pedestal, but is movable and adjustable for windage and elevation so that the barrel can be pointed at the target, which is a plain sheet of white paper of appropriate size.

Ranges vary from a common 100 yds. for most rifle cartridges up to several hundred yards for centerfire match ammunition, and down to 50 yds. for pistol and revolver ammunition and ordinary .22 rimfire.

Match-quality, .22 rimfire cartridges are checked at 100 yds. or 100 m, sometimes with the Mann type of barrel and sometimes with a match rifle in a special rest.

There are several ways of measuring accuracy, given a group or a series of groups.

Extreme spread, the distance between the widest two shots in the group, is the simplest method and quite reliable, but it doesn't take into account directly the difference between horizontal (H) and vertical (V) dispersion.

Large variations in muzzle velocity can create differences in the location of vertical impact on a target, but have little effect on horizontal dispersion, so that, by measuring and reporting H and V dispersion separately, a better analysis of any inaccuracy is possible. Averaging H and V dispersions gives the "Figure of Merit," a somewhat more precise estimate of accuracy.

The Army takes great stock in using the Mean Radius as its method. Mean Radius is determined by averaging the distance of each shot in the group from the centroid of the group, obtained mathematically or graphically. The Mean Radius approach minimizes the effect of one extremely wide

shot in a group. In a 10 shot group, one shot falling three inches from the center of what would otherwise be a 9 shot group measuring one inch in extreme spread would increase the extreme spread by 2½ inches to an approximate 3½ inches from the 9 shot 1" group. Mean Radius of the 9 shot group would be approximately .3", while that of the 10 shot group with the flyer would be about .6".

Opinion varies on the merit of this measurement versus the others. *Figures 64 and 65* show how each method is applied to a group:

Mathematically, it is possible in a series of groups to estimate two of the three measures, given the actual measurement of the third, and it is possible to estimate any one of the three factors for shot groups having a greater or lesser number of shots.

Taking the Average Extreme Spread of a number of targets as a factor of 1.00, Table 9 gives conversion factors for Figure of Merit and Mean Radius for 3, 5, 10, and 20 shot groups.

For example, if a series of 10-shot groups had averaged 1.60" extreme spread, multiplying 1.60 by the factor .812 would give a figure of 1.30". This is the average that would be expected if the same shooting had been in 5-shot groups rather than 10.

Going a step further, if a series of 5-shot groups had produced an average extreme spread of 3.00", the Mean Radius for 10-shot groups can be estimated by dividing the 5-shot average, 3.00", by the factor .812 to give an estimated average extreme spread of 3.69". Multiplying 3.69 by the 10-shot Mean Radius factor of .308 would give an estimate

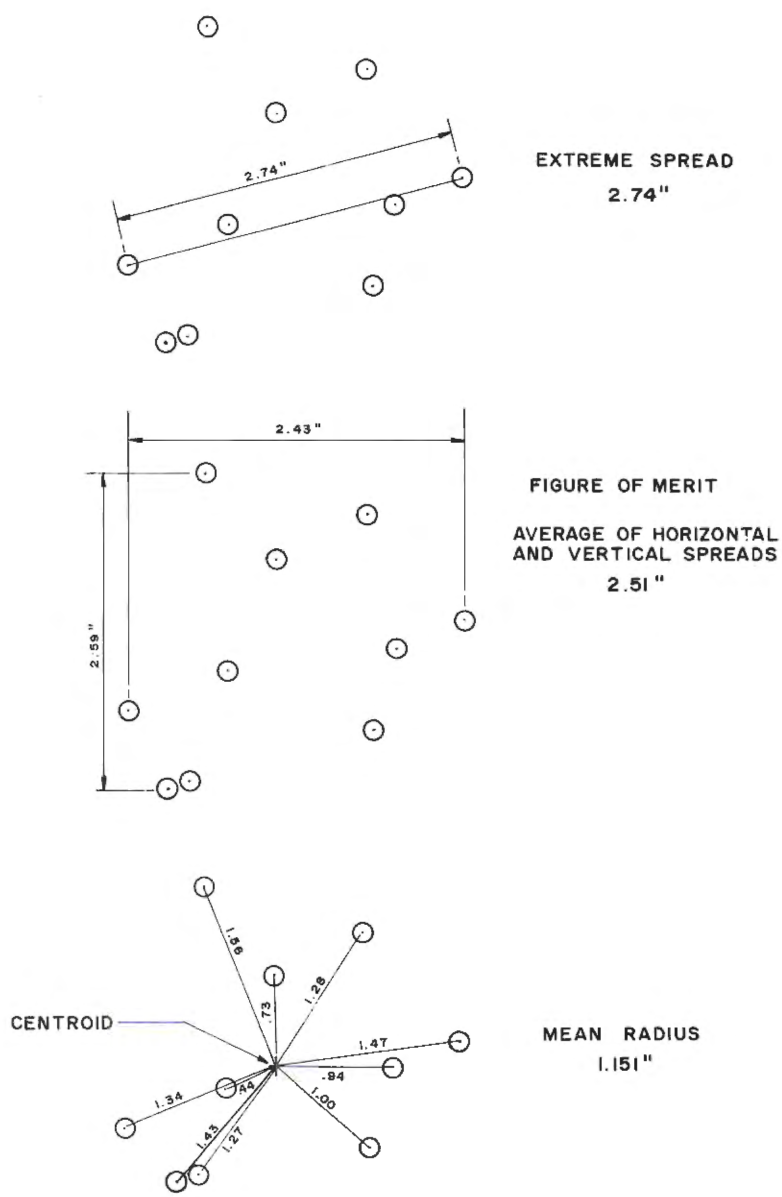
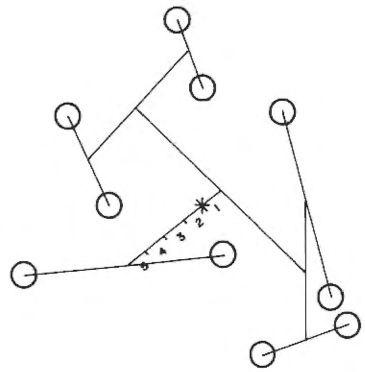


Figure 64: Three Methods of Measuring Shot-Group Size



CONNECT ANY FIVE PAIRS OF LINES.
CONNECT THE MIDPOINTS OF ANY FOUR LINES WITH TWO LINES.
CONNECT THE MIDPOINTS OF THE LAST TWO LINES WITH ONE LINE.
CONNECT THE MIDPOINT OF THE LAST LINE WITH THE MIDPOINT OF THE REMAINING LINE. ONE FIFTH OF THE WAY ON THIS LINE IS THE CENTROID.

Figure 65: Finding the Centroid

of 1.14″ for an average 10-shot Mean Radius.

The conversions don't necessarily hold true on single group comparisons, there being too much variance between groups. So long as a reasonable number of groups is fired, however, it is possible, using the above conversion factors, to compare accuracy from 5-shot groups with accuracy from 10-shot groups by averaging group sizes with each series of groups and applying the appropriate factor. Suppose that twenty, 5-shot groups averaged 1.65″ Extreme Spread with one ammunition, and in another test twenty 10-shot groups were reported as having a Mean Radius averaging .61″ with a similar ammunition. Which ammunition is the most accurate?

Converting the 10-shot Mean Radius average to an equivalent 10 shot Extreme Spread, simply divide the Mean Radius by the 10-shot conversion factor, .308.

$$.61 \div .308 = 1.98'' \text{ Extreme spread}$$

Multiply this by the 5-shot Extreme Spread conversion factor, .812.

$$1.98 \times .812 = 1.61''$$

Comparing this with the 1.65 Extreme Spread from the 5-shot group shooting, it will be seen that the ammunition fired in 10-shot groups was slightly more accurate.

The problem may also be worked in reverse:

$1.65 \div .812 = 2.03''$ for 10-shot equivalent Extreme Spread
$2.03 \times .308 = .625$ Mean Radius

Again, it will be seen that the 10-shot group ammunition was more accurate.

In day to day control testing, the factories generally use extreme spread. It's easy to measure and record. With the large number of groups fired, the conversion factors covered earlier give reasonably valid estimates of other means of measurement.

Usually 10-shot groups are fired, in the interest of convenience. Time for changing the targets between 10 shot groups is the same as for 5-shot groups. Time to measure a 10-shot extreme spread is no more than for a 5-shot group, and is taken only half so often. Twice as many target changes and twice as many measurements make more work for the busy ballistic department.

Bullet Pull

A necessary control in all metallic ammunition is that of bullet pull.

The amount of force needed to pull the bullet from or push the bullet into the case has an effect on ignition, velocity, pressure, and accuracy from the ballistic side. On the user's side, bullet pull also has to do with good functioning.

If, in the case of a revolver under recoil, the bullets in the unfired chambers start to move out of their cases, the cylinder may jam on the nose of the bullets. Similarly, in the magazine of a heavy-recoiling rifle, bullets will be struck on the nose by the recoiling magazine, pushing the bullet back in the case if the pull (or push) is too low. This condition leads to possible jams in feeding and also to increases in pressure, as the powder space in the case is reduced.

In rimfire ammunition, bullet pull is controlled by rolling the mouth of the case into the soft heel of the lead bullet. If too heavy, this crimp may tear or scrape off part of the heel or may mutilate it so that accuracy is affected. A heavy crimp increases

Table 9: Mathematical Relationships of Measures of Accuracy

Shots in Group	Extreme Spread	Mean Radius	Figure of Merit
3	.637	.265	.438
5	.812	.290	.602
10	1.000	.308	.796
20	1.166	.316	.966

breech pressure, while a light crimp may lead to uncertain ignition and low pressures and velocities. Ultimately, it may thus lead to poor accuracy, if the powder used does not characteristically call for light crimp.

Average rimfire pulls range anywhere from 30 lbs. up to as much as 70 lbs. Match ammunition is usually loaded with a powder that performs well with a light crimp, so that bullet damage in firing is minimized.

Military ammunition usually calls for a fairly heavy crimp and high bullet pull to make sure the bullet stays in place until fired. Feed failures in automatic weapons from short rounds caused by bullets being pushed in during feeding causes unhappiness among soldiers.

At the same time, the crimp aids the military-type sealing compound at the mouth of the case in keeping the round oil- and waterproof.

Centerfire pulls may range up to 100 lbs. or more.

With a bullet diameter of .2235", the chamber pressure needed to create a direct force of 70 lbs. on the bullet is 1780 p.s.i. The peak pressure in a 22 L.R. cartridge averages as high as 24,000 p.s.i, so there is not much question about the bullet leaving the case.

Similarly, a .30 cal. bullet, diameter .3085", bullet pull 100 lbs., starts to move as the chamber pressure moves past 1338 p.s.i.

Friction alone between case neck and bullet is seldom heavy enough to hold the bullet in place if recoil is heavy. The knurl on the bullet solves the problem. Crimping the case mouth into the knurl effectively stops the bullet from either being pushed into the case or pulled out under recoil.

Bullet Upset

For the benefit of hunters, much work has been done on developing bullets with desirable expansion characteristics. The results are much publicized in advertising.

Here, the ammunition maker walks a tightrope. Opinion among hunters is far from universal as to what constitutes ideal hunting bullet performance.

Some hunters insist that a bullet must pass entirely through the animal, so as to make the game leave a blood trail by which it can be tracked.

Others want instant kills with minimum meat damage. Bullet energy is to be applied in such a way that, regardless of where the animal was hit, it falls over dead on the spot with only a steak or two bloodied a bit. As the saying goes, however, "You can't make an omelet without breaking eggs." Some meat is bound to be damaged.

The majority of hunters, however, seem to feel that a bullet should pierce the outer animal layers, open up or expand in the so-called "boiler room," and stop on the far side of the animal, after having expended all its energy. This is better thinking.

All these varied things the hunter expects to happen, surefire, at any range from pointblank to as far as he can see with either telescope or eye, which is wishful thinking. Velocity change with range is too great.

Further, with the exception of blunt-nosed bullets intended for tubular magazines, the bullet is to have a sharp pointed profile, and even a boat tail to keep remaining velocities at longer ranges at a maximum.

Somewhat like a fishing lure, which to be successful has to appeal both to the fisherman and the fish, the bullet needs eye appeal.

Inside the animal, the bullet, except for the hollow point, is expected to expand nicely to double or better its original diameter. At the same time, core and jacket must stay together.

There are been many letters written by hunters, who have sent in bullets recovered from their game, complaining sometimes loud and long about upset appearance. The fact that the bullet was recovered would tend to indicate some degree of success on the hunt. The whole scene was spoiled for the hunter because the bullet and/or the game was expected to do something different.

Short of shooting game animals, the ammunition maker tests his bullets in several media, the commonest and cheapest being water. Shot downward into a tank of water five ft. or so deep, the bullet can be recovered using a screen hauled up from the bottom. Velocity can be adjusted to correspond to the range desired. Water should be as much as five feet deep. Gelatin is also used, but is expensive.

Here it could be argued that reducing muzzle velocity to correspond to a longer range overlooks the decreased rate of spin. This is true, but the rotational energy of a bullet is so much less than its linear energy that the difference is not really significant. For example:

The rotational energy of a 150 gr., .30 cal. bullet, fired from a 1-10" twist barrel, at a muzzle velocity of 2800 ft./sec. is 13.2 ft. lbs., only about .5% of its linear energy of 2600 ft. lbs. Cutting muzzle velocity in half to correspond to a longer range would reduce spin energy by 6.6 ft. lbs., still only .25% of the total bullet energy.

A bullet does not lose its spin as rapidly as it loses velocity. In any event, the energy difference is less than the linear energy differences due to velocity differences between shots.

Gelatin is a good test material. It comes close to resembling flesh in consistency and density, and can be remelted and reused.

Wood, usually clear pine, is frequently used to compare penetrations. Inch-thick boards can be separated slightly and the passage and progress of expansion from board to board can be noted. Only

a limited number of rounds can be tested before the boards get too chewed up, though, and pine lumber is no longer anything like cheap.

Old telephone directories work fairly well, and the scrap paper value is but little diminished.

Under the stress of firing, a bullet may change shape in the barrel. For this and other reasons, it is sometimes desirable to recover fired bullets in as undamaged a condition as possible.

Shooting into water is out; it causes expansion. Cotton waste has been used, but also causes damage. One of the best materials used so far is polyurethane foam in blocks. The density of the foam should be in the neighborhood of $1\frac{1}{2}$ lbs per cu.ft. Blocks $1\frac{1}{2}$ by $1\frac{1}{2}$ feet square and 3 to 4 feet long are lined up end to end. Penetration may be as much as 20 feet. If the bullets tend to run off course and escape the blocks, larger blocks may be placed at the far end of the line. Putting a sheet of paper between each block makes it easier to find the bullet. Bullets recovered from this material show virtually no damage from being stopped.

Hollow-point game bullets are supposed to act somewhat the same as varmint bullets, coming apart rather violently in the animal and creating a maximum of damage. Trophy hunters, not meat hunters, are more apt to choose them. Testing in water checks the ultimate blow-up. Testing in wood gives an idea of penetration before expansion starts.

Patterns

Shotshell patterns are not always shot every day, but are certainly checked any time there is a change in wadding, shot, primer, powder or loading conditions, or on any experimental loadings.

I had an early introduction to patterns.

On my 14th birthday, I got up early in the morning, curious as to what the day might bring. At breakfast, my father casually mentioned that Billy McGowan, down at McGowan and Sheridan's Hardware, wanted me to drop in. Which I did forthwith; on suspicion.

Mr. McGowan handed down from the gun rack a brand new and beautiful 20-ga. single shot shotgun, reached under the counter and brought up a box of 20-ga. Peters shells. The gun was from my father, and the shells and congratulations were from the store.

Now, this was in August, and the pheasant season wasn't until early October, three coons' ages away. The idea of simply banging a shell or two into the air was kid stuff and not for a proud new gun owner. Still there had to be some sort of action somewhere. Dad had fixed that, too.

An old family friend, Rufus Wood, came in about then and mentioned that, while it was a pity there was nothing to hunt, I could at least learn more about my shotgun by patterning it, which was a new term to me. He produced some large sheets of paper, and we repaired to the farm and to a convenient haystack. He stuck a sheet against the haystack, and we paced off 40 yds., and he handed me the gun. He showed me how to hold it so the kick wouldn't bruise my upper arm, and how to stand so I wouldn't be thrown off balance. Then I loaded the gun and fired at the target. The kick was a little more than I had anticipated, but no bruise. I shot two more patterns. Then we went back to town.

Next we carefully cut open one precious shell, poured the shot out and counted them. With a yardstick, a piece of string, and a pencil, we drew a 30″ circle around the greatest concentration of pellet hits on each of the targets. Then, marking each pellet hit with the pencil as I counted it, I counted the number of shot holes inside each 30″ circle. Dividing these totals by the number of shot in the shell gave us the pattern percentage, and I got my first lesson in ballistic testing.

Years later, when I went to work at Western, pattern testing followed the same sort of procedure, with some refinements. First, shells were hand loaded with a precounted number of shot. Second, we used a clear plastic, 30″-diameter disc to locate the densest portion of the shot pattern, and as a template around which the containing circle was drawn. With those two changes the drill was the same one that Rufus Woods and I had followed using my birthday 20-ga.—only a ballistic lab shoots more than three shoots, a lot more.

If that crew out in Lewiston, Idaho who bill themselves as "The Good Ol' Boys", wear their hunting clothes as if they mean it, it's no accident. One can't get much closer to larger than life, hunting and fishing country, and still operate a large scale ammunition business than they do.

Around Lewiston, quail run across the yard to water every evening. There are steelhead in two rivers that run along the northern and western borders of the city. Deer roam the hills 30 minutes away, trout swim in the small streams, elk are found a little farther off in the high country, and chukar partridge roost in the canyons. It's easy to use up spare time. Indeed, it's not unusual to sneak a little extra time-off; like shooting pheasants during a long, instead-of-a-martini, lunch hour, for instance.

Guns and ammunition get a good work-out. Bullets get practical testing in the field on real live game. All in all, it's a wonder that CCI and Speer manage to get as many primers and bullets made as they do, and good ones too. The lure of the paycheck seems to draw a few of the "Good Ol' Boys" back to the plant once in a while.

Visitors passing through Idaho and neighboring Washington drop in to say hello, talk about the

product, mention hunting and shooting, and with a little encouragement, talk about their own successes in the field.

Once the late George Fairchild, then Vice President for Sales, and I were talking to an Easterner on his first trip west. In the flow of conversation, the visitor courteously asked George if he'd had any luck hunting that year. In the east, the answer expected would be a sad no or a big yes, with full details, no's outnumbering yesses by a wide margin. In Idaho, the answer would be one of degree; how many, how big.

"Nice fat doe last week," George told him.

"Where'd you get it?"

"Deer Creek," says George, a bit astonished, as there wasn't any need to ask the obvious. The fellow thinks George is maybe guarding a secret, so he lets it drop, and asks me how I did.

"Elk."

"Now I'm afraid to ask where."

"No problem, Elk City, of course."

So then we had to bring out the map to show the man both answers could be true, which they were.

Primer Sensitivity

Granted that the firearm is in good repair and administers a firing pin blow adequate to fire the cartridge, the key to whether or not ignition takes place is the sensitivity of the primer. The primer must be sensitive enough to fire under any reasonable blow, yet must not be so sensitive that the shock of feeding and closing the bolt, or of accidental dropping on a hard surface could set it off.

In order to control sensitivity within this range, special drop test apparatus, relying on Mr. Newton's predictable gravity, is called into use. The raw data from drop testing is then analyzed by statistical methods. The resulting indexes are used for comparison against standards.

The equipment consists of a holder representing a standard chamber for the shell, pointing down. Over this holder, a cap, containing a firing pin of standardized shape, is placed (See Fig. 66). Over this cap is poised an electromagnet holding a steel ball. The magnet is adjustable for varying heights above the firing pin so that the ball, on release by the magnet, may fall freely a measured distance to strike the firing pin. The height of the drop above the firing pin is measured from the bottom of the ball to the top of the firing pin as it rests against a primer case in the holder.

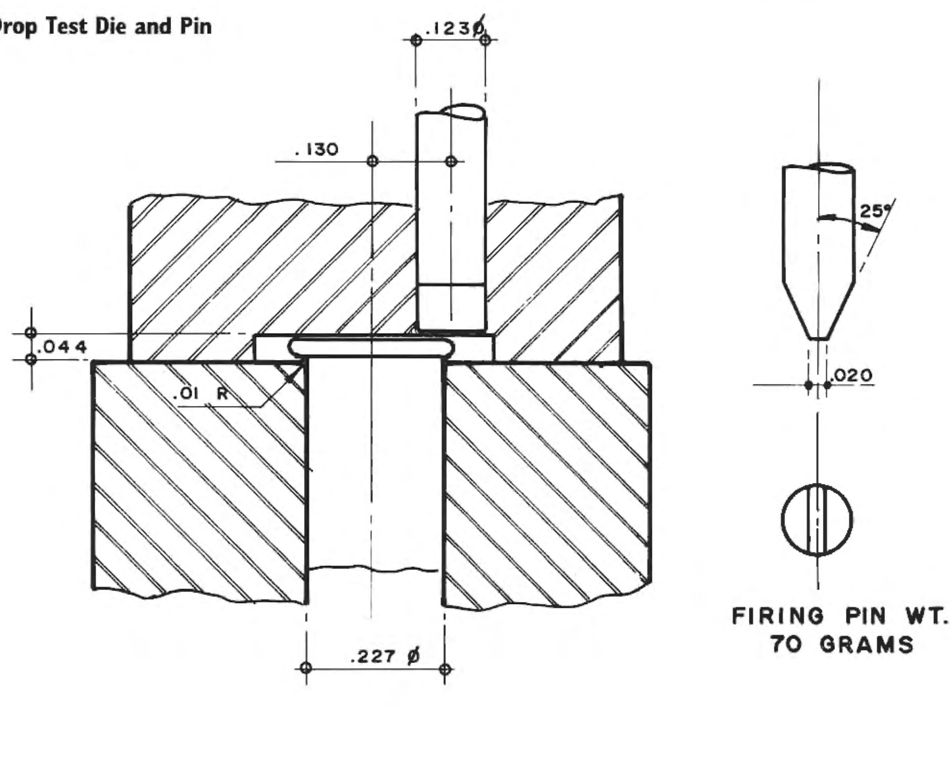
Sensitivity is determined by making what is called a "run-down" test on a quantity of primed shells or primers placed one by one in a steel die.

Starting at a height where some primers fire when the ball is dropped, a sample of anywhere from 25 to 100 primers is successively tested and a record is kept of how many fail. Drop height is then decreased by an inch and another sample of equal size is tested. Height is further reduced in 1" increments until a point is reached where none of the primers in the sample fire.

Then, going back and starting at a height 1" above the starting height, samples are tested at successive, 1" increases of height, until all primers in the sample fire. Statistical analysis, based for purposes of this example, on the data shown in Table 10, follows the actual testing.

First, the decimal fraction of primers misfiring at each height is calculated. These decimal fractions (actually percentages of misfires if multiplied by

Figure 66: .22 Rimfire Drop Test Die and Pin



100) are used to calculate two indices, $\overline{H}$, the theoretical height at which any primer tested would have an equal chance of firing or not firing, and S, a measure of the uniformity of the primers' sensitivity.

$\overline{H}$ bar, the mean critical height, is calculated by adding up the total of the fractions misfiring, adding the height at which all primers misfired, plus an additional one-half inch, expressing the whole in inches.

S is computed from the following formula:

S = Total P_iK_i - (Total $P_i)^2$
where P_i is the fraction misfiring.
K_i is a standard deviation factor, 1, 3, 5, 7, 9, etc.

Here is a sample calculation: 25 primers tested at each height

Table 10: Critical Height Calculations

Drop Height Inches	Number Misfiring	P_i	K_i	P_iK_i
10	0	—	—	—
9	1	.04	11	.44
8	2	.08	9	.72
7	6	.24	7	1.68
6	12	.48	5	2.20
5	18	.72	3	2.16
4	24	.96	1	.96
3	25			
Total Fraction		2.52		8.16

$\overline{H}$ = Total Fraction misfiring $+ H_{100}$ $+ .5''$
= 2.52″ + 3 + .5
= 6.02″, the mean critical height
S = Total P_iK_i − (Total Fraction not firing)^2
= 8.16 − $(2.52)^2$ = 8.16 − 6.35
= 1.34″

At a drop height of 6.02″, $\overline{H}$, it would be expected half the primers tested, on the average, would fire, half would not.

Notice that at the 6″ level in the data above, 12 primers failed to fire, 13 fired—a close prediction. A sample large than 25, say 50 or 100, would give an even closer approximation.

Both of these indexes are used to judge the probable degree of sensitivity of the primers. $\overline{H}$ − 2S gives a height at which not more than 4 primers in 900 would be expected to fire, while at heights of $\overline{H}$ + 3S not more than 3 primers in 100,000 would be expected to misfire. $\overline{H}$ + 4S lessens the chance of misfire to 3 in 1,000,000 and $\overline{H}$ + 5S reduces it still further to 3 in 10,000,000.

In U.S. practice, two different weights of ball are used, one weighs 1.96 ± .02 ounces, the other weighs 3.94 ± .02 ounces, nominal diameters are 15/16 and 1-3/16″ respectively.

In order for the ball to be uniform, the firing pin must move freely and the ball must hit it dead center. Putting a piece of carbon paper over the upper end of the firing pin before dropping the ball will leave a mark which will aid in centering the ball. This is always done when changing drop height.

In use the top of the firing pin tends to become rounded off, and must periodically be ground flat.

In theory, a 2 oz. ball dropping 16″ will produce the same results as a 4 oz. ball dropping 8″, but the actual results may be slightly different. Sensitivity to some degree depends on speed of impact of firing pin. From a 16″ drop, a 2-oz. ball is moving at 9.27 f.p.s. when it strikes the pin, while a 4-oz. ball falling 8″ reaches a velocity of 6.55 f.p.s. The energy of each ball at time of impact is the same, 32 in.-ozs., or .167 ft.-lbs.

The 4-oz. ball would relate more to the sluggish blow of a heavy firing pin or hammer with short travel. Then, too, having to fall only half as far, the heavier ball makes it easier to line up on the firing pin. The lighter ball spreads the distance between 100% firing and 100% misfiring twice as far, giving more refinement to $\overline{H}$ and S determination. Of course, the value for $\overline{H}$ and S will be doubled.

Centerfire and shotshell primers are tested either in a steel fixture or in shells. The steel fixture produces a little lower $\overline{H}$ reading, but rimmed shells give about the same reading. In the shell pocket the primer is seated so that the anvil is pushed into the mix a little deeper, sort of pre-stressing the primer. Sensitivity is then slightly better.

Rimless cases give $\overline{H}$ readings an inch or so higher, as the case seats against the shoulder of the die on an angle cushioning the blow somewhat. This condition is worsened if the shoulder area is too soft, as a result of mouth anneal.

Some normal ranges for $\overline{H}$ and S are shown in Table 11:

Table 11: Normal Ranges for $\overline{H}$

Primer	Ball Wt. (oz)	$\overline{H}$ range (inches)	S range
.22 rimfire	4	2.7 to 3.7	.75 to 1.5
	2	5. to 7.0	.75 to 1.5
Small pistol	2	3.5 to 5.5	.75 to 1.5 rimmed case
Large pistol	2	5.0 to 7.0	1.1 to 2
Small rifle	2	6 to 8	1.0 to 2.0 rimless case
Large rifle	4	5 to 7	1.0 to 2.0 rimless case
Shotshell	2	4½ to 6	.75 to 1.5 in shells
	2	3½ to 5	.5 to 1.2 steel die
	4	3½ to 5	.65 to 1.5 in shells

Not every primer test is a full run-down. Control samples taken from production are tested at a height and in a quantity where no misfires would be expected to occur, but where an inch less drop would tend to produce some misfires. If misfires occur during the test, a choice has to be made as to whether to make a full run-down or to test a larger sample at the single height.

As to permissible limits of sensitivity in the overall, most rifle cartridges should not fire under a blow administered by a 2-oz. ball falling 3". All rimless should fire at a drop of 25". Rimmed cartridges should all fire at 20". The figures for pistol and revolver cartridges are 1" and 11" for rimmed cases with small primers, and 2" and 16" for cases with large primers, with 2-oz. ball.

For shotshells, it's 1" and 14", and for rimfires 1" and 16.5", 2-oz. ball.

Back in the years when most centerfire competition was fired with a revolver, usually .38 Spl, it was customary for some shooters to lighten the mainspring, making the revolver easier to cock. It was not infrequent to hear complaints that one brand of ammunition would give some misfires, while another brand did not. In these cases, the blow had been lightened so much that the revolver was differentiating between the two $\overline{H}$ levels of the two different ammunitions, which may have been less than 1" apart.

Function Testing

Function or "random" testing, where ammunition is tested in a series of firearms representing those to be found in users' hands, would seem to the outsider who likes shooting to be but one step removed from paradise. New employees in the ballistic department usually spent their first few days in the random pit shooting at anything that looked like a target in the sand-filled pit. With the first surge of unlimited shooting for pay out of their systems, the job tended to get closer to monotony. At the same time, experienced shooters could and did detect anomalies in cartridge performance of quite subtle nature.

A hangfire, a delay in firing after the firing pin hits, is, at its worst, a "click-bang" sort of thing, with a tenth of a second being of long duration. At .1-sec., almost any shooter would instantly be aware of trouble. A .01-sec. delay, easily detectable with laboratory instruments, would also be apt to be noticed by an alert, experienced function tester, simply because the shot would sound a little out of rhythm.

I recall one time at Western when a function tester reported that the shotshells he had been shooting felt a little "slow." Further testing of the shells for ignition-barrel time proved he was right, the barrel time was longer than normal. In this case, however, the degree was far less than would be imagined.

A shot charge fired from a 12-ga. high velocity load leaves the muzzle of a 30" barrel at about 1330 f.p.s. The time elapsed from the strike of the firing pin, to shot leaving the muzzle, in other words, the ignition-barrel time is a little over 3 milliseconds (that is .003-sec.). The ignition-barrel time on the loads the shooter felt were "slow" was a little over 5 milliseconds. Thousands of rounds of random shooting had sharpened this shooter's perception almost beyond belief.

Which brings to mind another time when a shooter, testing .44 Mag. loads for the first time, came in with a pained expression. He reported that the revolver was doubling. It was firing two shots at once. Now everybody knows that, with the exception of a muzzle-loader which flashes over sometimes, a revolver can't double. But the shooter was adamant. He had loaded six rounds into the cylinder, fired once, opened the revolver and found two rounds fired, with no damage to the revolver. Amid much skepticism, out came the Fastex Camera, taking pictures at rates up to 3000 per second.

Lo and behold, the man was right. The film clearly showed that, as the revolver recoiled, it moved away from his trigger finger enough to engage the double action sear and then bounced forward from his work-toughened hand back against his still coiled trigger finger to fire the second time.

The actual amount of firing to be done depends on the loading system, the cartridge or shell being loaded, and the nervousness, or lack of it, of the manufacturer. Two things are particularly to be guarded against: missing powder charges, and incorrect powders.

Take .22 rimfire for instance. A quantity of 500 to 1000 cases is shaken into holes in a plate and placed under a pair of sliding plates holding the powder charge. By shifting the upper powder plate, the powder charge is dropped into the shell. A bullet plate is set atop the charged case plate. The sandwich of plates is placed in a seating press and the bullet seated.

If the lunch bell rings early in this loading cycle, the powder charger may forget to drop the powder charge, and 500 or 1000 cartridges end up powderless. If these get mixed in the rest of production, there are then an equal number of chances for an unhappy customer.

By taking one cartridge from each plate as it is loaded, a plate of missing powder charges will immediately be found by the function firer.

It follows that ammunition is not carelessly mixed before the function firer has passed it, otherwise several hours' or a whole day's work might be contaminated. There isn't any way to look at a .22 rimfire cartridge and detect missing powder. The

whole mixed lot will have to be scrapped, or diverted to in-plant testing—if you are fortunate enough to have a gun plant, also.

Similarly with mixed or incorrect powders. In most loading areas, several different calibers are being loaded at one time. A powder handler brings, or is supposed to bring, the correct powder to each loader.

Maybe on a Monday, after a holiday, or in the heat of spring, the incorrect powder is delivered to one of the loaders—say Bullseye where 2400 is supposed to be. The alert powder charger should immediately see the difference. If he doesn't, it will be the function firer's bad luck to run across a really high pressure round, but the error will be caught. These things shouldn't happen, but, if people can make mistakes, they will.

Where loading is by machine, samples are taken from the machine at specified intervals. Unchecked ammunition is kept segregated until the sample has been shot and okayed.

Besides the missing or incorrect powder, the firer is on the lookout for misfires, split cases, dropped or loose primers, hard extraction, squibs and poor ignitions mentioned earlier, odd sounding shots, problems with chambering or feeding, burst heads, or any other deviation from normal.

Fired cases are inspected before scrapping. Shooting is done in several guns, all types to be found in the field, some old, some new.

Powder Evaluation

Naturally, the ballistic department has a great deal to do with powder. It is up to the lab to select or recommend a powder or powders for a particular load. In this regard, the factory may want to make a choice based on relative powder charges and powder costs. Economics may call for some compromise between a relatively more expensive ideal loading and a less expensive powder or lower powder charge giving ballistics within specification.

The department also has to evaluate new powders for possible use and has to check all incoming lots for acceptance.

There are several things to check:

Pressures and velocities in a range of charges and calibers
Port pressures
Ignition and barrel time
Accuracy
Pressure, velocity and functioning at −40°
Stability
Density

On established loadings with standard powders, it might seem that all of these tests are not always necessary. A fresh lot of a known powder, if pressure and velocity results are within the normal range for a given powder charge, usually goes into production without much fuss. Even so, it is only prudent to carry out all the normal tests. It could save a lot of trouble later.

Powder Moisture and Volatiles

Moisture, if present in an excessive amount, can cause deterioration more rapid than normal. Powder manufacturers are careful about moisture in their outgoing product, but shipment and storage may conceivably either add or remove moisture.

Moisture content of a powder lot is determined by heating a weighed sample for two hours at 100° C, and reweighing it. Any volatile material in the powder, including water and solvents used in manufacture, is driven off. Hence, moisture and volatile material contents are usually determined as one item. Moisture and volatile material content for modern dense smokeless powders ranges from about a half percent to a little over 1%.

Modern smokeless powders contain very little moisture, and are compounded with stabilizers which immediately react with any products of decomposition. Storage life at ordinary temperatures can be reckoned in decades.

Nevertheless, the need sometimes comes along to check a powder for stability. The 30 years that good powder lasts in normal storage is too long to wait for results. Advantage can be taken of the fact that the higher the storage temperature the more the rate of decomposition is accelerated.

If time permits, the "65.6°C" test is used. Samples are stored in an oven at this temperature in clear glass test tubes and inspected daily until the red fumes of decomposition evolve. Test values of 20 days or less indicate inadequate stability, and the powder should not be used.

Powder manufacturers use other tests at higher temperatures, but the procedures are more complicated and call for special apparatus.

The apparent density of the powder is checked by weighing a given volume. Powders varying greatly from the expected average density may give trouble in loading by occupying too much or too little space.

Other Tests

There are other less-routine tests that the ballistic group performs. In certain cartridges, mostly pistol and revolver, the powder space in the case is considerably more than that needed for the charge. Such cartridges are usually hold-overs from blackpowder days, when the bulkier black powder needed the space. It is customary to fire samples of these cartridges muzzle down, to detect any tendency toward poor ignition with the powder at maximum distance from the primer. The care

that must be taken so as not to shoot oneself in the foot is optional.

Cartridges that are likely to be used out of doors in cold weather must be checked for the effects of low temperature on ignition. Low temperature shooting also magnifies any tendency toward slow ignition and hang-fires. The ammunition is placed in a freezer for several hours before testing to cool the powder to −40°. Testing of ammunition at −40° quickly brings out any weakness in the ignition system. Velocity, pressure, ignition time, and random shooting are all checked.

Frequently, the test barrel or weapon is cooled as well. In any event, shooting is done as rapidly as possible, so that the ammunition doesn't have time to warm up.

A small insulated box is used to carry the test rounds from the freezer to range.

CHAPTER X
TROUBLES

It may come as a surprise to some, but the admission must be made that not all ammunition is perfect. Sometimes things do go wrong. Hopefully, the trouble is found before the ammunition leaves the plant, but by chance, not deliberately, the public may get a sprinkling of trouble. The ammunition company, if it is sensible, treats all consumer complaints as extensions of its own inspections. Prompt action is to be taken where necessary on the information fed back. Further, of course, proper adjustment is to be made with the customer. Action in this regard is a splendid opportunity to make a good friend. (In modern parlance, this is known as "improving customer relations.")

Not all complaints are justified, in fact experience shows that less than half are due to the ammunition maker's defects.

This chapter deals with various malfunctions and troubles which can occur with ammunition, inside and outside the factory. Some light is included as to how to analyze causes.

Included also are a few notes on damaged firearms, and the common causes for damage, including high pressure bursts, obstruction bursts, incorrect ammunition, 12-ga./20-ga., and 20-ga./28-ga. bursts.

Misfires

While a misfire may seem a simple occurrence, in that a cartridge fails to fire under the firing pin blow, the possible causes are many, and sometimes hard to pin down.

To most people, recocking and refiring with no effect points absolutely to a faulty cartridge, but that isn't necessarily so.

A light firing pin blow may dent the primer, but so gently as to not incite the primer to action. A light blow may, however—and frequently does—crack up the priming pellet. Successive blows then find no mix between primer cup and anvil to compress. Misfire.

Multiple blows, in examining a misfire, are usually easy to spot under magnification. In such a case, if no further cause for misfire develops on further examination, a light blow may be suspected, and can be confirmed by checking a single indent from the same firearm.

Once at East Alton, we had an exceedingly violent letter from a St. Louis hunter who demanded full restitution of the entire cost of his hunting trip, some $200 or $300, a lot of money in those days. He said he had a perfect shot at a fine Missouri buck and the gun misfired not once but twice, and he had the two shells to prove it.

Apparently the buck, weary of so much fevered fuss, with all the snapping and bolt slamming, left.

Now with Western the two successive misfires added up to something Western probably didn't do. One misfire by itself is not utterly surprising, although highly infrequent, but two in a row points, on the basis of odds, to something smelly in the local scene. Either the gun was haywire, or the cartridges weren't quite the same as when they left the plant.

Nobody makes ammunition that bad. If even poor, and really poor, ammunition were to produce misfires in a good rifle at the rate of 1 in 1,000, the odds of two consecutive misfires in the first two rounds shot stretch out to nearly 1 in a million.

A telephone call to the gent brought a renewed demand for soothing cash, also the word that he was shooting an '03 Springfield, and would receive my visit.

I took along an '03 rifle, some empty primed shells, and a couple of boxes of loaded cartridges as a possible peace offering.

This was wintertime, the temperature, as I recall, was maybe 20°F, the day was gloomy, and the man was loudly unhappy, and became even more so when I didn't immediately come up with a folding green dose of pain killer.

One glimpse of his two misfires was enough to see that they had been kissed but lightly by the firing pin. This, according to him, wasn't the answer. A National Guardsman, he had borrowed the rifle from the armory, cleaned it himself, and knew all about rifles. He did say he hadn't shot the gun before hunting, volunteered that it had been a cold day, and that it would be an even colder day in hell before he used our stuff again.

As lightly as the primers had been hit, it seemed like a good gamble to pull one of the bullets, dump the powder, and snap the shell in my '03. So doing, the shell produced a satisfactory, to me, bang. To him, it was an extra strong spring in my rifle.

So he dragged in his rifle from his car outside, where it had been sitting, nicely chilled. Snapping it produced a mushy "thwuck," about as emphatic as a butterfly's cough. The reason was simple. The bolt was still full of very stiff, heavy, cold cosmoline. Waving the firing pin and spring with its full load of glop at him may have won the battle for me, but the war still went on. As I left, with the

two conciliatory boxes of .30-'06 still unpresented, threats of writing all the gun editors about our lousy ammunition were showering down all around me. Win a few, lose a few. We never heard from a gun editor.

On shotshells, a misfire is frequently blamed on a "deep primer," a case where the misfire shows the primer cup, somewhat dented, pushed down in the battery cup, so that it is obviously well below the head of the shell. Here the evidence, other than that some sort of misfire has occurred, isn't all that plain. A light or slow blow, not enough to fire the priming mix, can create this appearance.

The shotshell primer is built a little differently than a centerfire rifle primer, in order to develop more sensitivity. A shotshell head, built of thin brass and paper or plastic base wad, and wide across the head, is not as rigid or firm as a smaller diameter rifle cartridge. The primer is not as well supported. More sensitivity is needed. The answer is to allow the primer cup, under the force of the firing pin, to slide easily down in the battery cup carrying the priming pellet down against the anvil. If the primer doesn't fire, it stays depressed in the battery cup. If it fires, the pressure inside forces the primer back against the face of the bolt. So, on a misfire of this type, further search for an answer is necessary.

As mentioned, shotshell primers are usually quite sensitive.

On one occasion, John Olin himself, called the factory to report that he had been standing next to a man who had a shell go off in his shooting coat pocket when he dumped a box of 12-ga. shells into it. Other than the startling bang, a certain amount of consternation, and a smudged shooting coat pocket, there was no damage.

The fired shell showed a peculiar dent across the primer, and a closer look identified it as coming from a shotshell rim. Apparently the shell, head down, had fallen squarely against the rim of a shell already in the pocket with enough velocity and inertia to fire it. Unusual, but it happened.

A centerfire cartridge of the rimless type may give rise to a type of misfire not due to primer. Since the case seats against the chamber on its sloping shoulder, small deviations in case diameter, and length to the center of the shoulder, are magnified by the slope, leading to larger changes in headspace length. It may even be that the headspace increase from an individual short cartridge will leave the firing pin protrusion too short to do the necessary, granted it was long enough to begin with.

Another cause may be a shoulder that is too soft. Unless the shoulder is reasonably hard and strong, the case may actually collapse under the impact of the firing pin and be driven farther into the chamber. Not only is the blow cushioned, but the protrusion mentioned before may not be enough. A misfired cartridge with a shoulder length markedly less than that of companion cartridges may well be suspected of being too soft. Here again, caution before jumping to a conclusion. Even with a shoulder of proper hardness, the firing pin blow will shorten a case .002" to .005" if the primer doesn't fire.

In case manufacture, after necking, the case neck

Table 12: Comparative Sensitivity of Off Center Firing Pin Blows

	Regular On Center Die		.020" Off Center Die		.030" Off Center Die		.040" Off Center Die	
Primer Brand	Brand R	Brand W	Brand R	Brand W	Brand R	Brand W	Brand R	Brand W
Drop Height								
21 in.								OK
20 "							OK	3 MF
19 "							4 MF	1 "
18 "							3 "	3 "
17 "							1 "	4 "
16 "						OK	4 "	4 "
15 "						1 MF	3 "	4 "
14 "					OK	1 "	4 "	7 "
13 "					1 MF	1 "	6 "	9 "
12 "					1 "	5 "	2 "	5 "
11 "					2 "	4 "	9 "	9 "
10 "				OK	3 "	1 "	11 "	19 "
9 "			OK	1 MF	4 "	5 "	17 "	22 "
8 "			2 MF	2 "	6 "	7 "	19 "	19 "
7 "		OK	3 "	3 "	11 "	17 "	24 "	19 "
6 "		5 MF	5 "	6 "	19 "	22 "	25 "	24 "
5 "	OK	7 "	8 "	16 "	24 "	25 "		25 "
4 "	10 MF	22 "	17 "	25 "	25 "			
3 "	20 "	25 "	25 "					
2 "	25 "							

and shoulder are deliberately annealed to relieve stresses that might cause season cracking later. This anneal is very carefully controlled by the manufacturer for precisely the reasons mentioned above.

In these days of handloading, fireforming, reforming, full length resizing and other manipulations by the handloader, some use for re-annealing shoulder and neck crops up. The reloader who does re-anneal must be doubly careful, or he may end up with a limp case.

At the factory level, light firing pin blows are judged by checking depth of indent against an indent coming from the drop test machine at a specified height. A dial indicator with a point sharp enough to reach the bottom of the indent is used to measure the depth of indent below the head of the case. A rimfire indent should be at least .010", with a well shaped firing pin. Appreciably less will be apt to bring on a no-fire situation part of the time at least.

A typical centerfire rifle, having a hemispherical firing pin tip, should indent a primer to a depth equal to about twice the diameter of the pin.

In comparing indents, dummy primers or desensitized primers should be used. Otherwise, in firing the primer may set back around the pin, giving a deeper than expected indent. In rimfire testing, there isn't much difference between primed and unprimed shells as regards indents.

So much for light blows. An off-center blow causes almost the same trouble. The force of the blow is spent denting more metal than necessary in order to crush the priming.

My notes include a test once run to see the effect of off-center blows in shotguns. Some types of guns in particular seem to have some trouble with hitting the primer perfectly dead center.

To eliminate the shotshell head strength variable, special steel dies holding the primers were used. Four dies were used, one dead center, one .020" off-center, one .030" off-center, and one .040" off-center. The test was made using a 4 oz. ball. Results are shown in Table 12. Twenty-five primers of each of two brands were tested at each height.

It seems that some misfires can be blamed on light blows, others on off-center blows. What else?

Consider these possibilities:

No priming
No flashhole
Improperly assembled primer
No powder
Improperly seated primer
Poor rimfire cavity shape
Insensitive primer mix
Metal in cup or rimfire too stiff or thick
Unevenly filled head cavity (rimfire)
Deteriorated, wet or contaminated priming
Dirty components—case, anvil, cup, or rimfire shell
Deteriorated powder
Chance

The first entry on the list is rather obvious, and in a well run ammunition plant is so infrequent as to be cause for major consternation and a thorough dusting-off of all controls on quality, one of which must have slipped. Even on a Monday, or the day after payday, it shouldn't happen.

Almost as bad is the no flashhole blooper. Most production priming machines have a flashhole detector just ahead of the primer inserting punch. If the probe doesn't find a flashhole, no dice. The machine grinds to a halt and the operator has to find and remove the unpierced case. The blooper comes when the probe breaks or is improperly adjusted and is not noticed. Some people even put the pierce on the priming machine, followed by the probe, and then the seating punch. This may be a little more complicated, but two punches have to go wrong to make a booboo.

Primers are made under highly systemized conditions which are supposed to, and do, insure a high degree of uniformity and freedom from simple manufacturing defects. Even so, an occasional anvil fails to get seated properly, or may be upside down, and is missed by an inspector. Such a primer is bound to misfire and does. Inspectors, as well as operators, being human, do sometimes miss such things, although very infrequently.

The infrequency is helped by the fact that primers are loaded by a plate loading system, 500 or 1,000 at a time. An empty hole in a plate supposed to be full of anvils shows up sharply by contrast. Also, an inverted anvil, which is supposed to fall out of the plate in manipulation, but doesn't, shows up by contrast.

Further, it is normal practice to lightly rake the plate of primers after anvil seating, so that any possible loose anvils are detected and the unanvilled primer thrown out.

Visual acuity of all operators who work on repetitive things does wane during the day to a marked extent, partly through fatigue, partly through a sort of mild hypnosis from the unending procession of identical objects passing by. Once in a while then, a not-quite perfect primer slips past. Not dangerously, unless there is a charging lion to be stopped, but certainly with some inconvenience.

A no-powder charge cartridge makes what is usually classed as a misfire. Rare, because loading conditions are especially set up to guard against it. Such cartridges seldom happen individually.

If the loading machine runs out of powder, automatic probes stop the machine. If the probe doesn't work, a lot of unpowdered shells will be produced. These will be found at function firing and the whole production will be held up. Or, in the case of military ammunition, where automatic

weighing machines are used, the cartridge with a light or missing powder charge will be thrown out.

In any event, a single cartridge found without powder is a signal for much fuss and to-do, searching questions, and culprit seeking.

It sometimes happens that a heading defect in forming a rim-fire case leaves an inadequate or poorly shaped head cavity. The priming doesn't get well spun into the cavity, leaving a void. A firing pin blow over the void produces no bang. It happens, but seldom.

Rimfire case making, as discussed earlier, calls for finely tuned machines, reproducing each step with little variation from case to case. A very few cases, trimmed too long or too short before heading, produce heads that are off-sized, too big or too little. Automatic gauging machines check every head as the shell comes off the header. The really odd-sized ones are sorted out. Borderline cases are a little more prone to misfire, so it pays to stay within gauge.

On centerfire primer seating machines, the primer is picked out of the reservoir, centered over the primer pocket, and pushed into place by the priming punch. The fit between primer and pocket is tight. The pace of the machine is rapid. It follows that sometimes things are not perfectly centered and the primer gets mutilated, or sometimes even turned over in feeding. Visual inspection, usually on 100% of the finished cases, finds these. If not, misfire.

There can be such a thing as unusually insensitive primer mix. Since all priming is checked more than once, before and during primer loading, misfires from this cause are pretty much confined to the factory.

Soap or other material left in rimfire cavities or in primer cups or improper washing is bad for priming, causing deterioration, poor adhesion to the metal, and eventual, if not immediate, insensitivity.

"Hard primers," a cause frequently assigned by the shooter, rarely happen. Metal thickness and hardness are checked before the metal enters the manufacturing process. Hard metal doesn't draw correctly, making poor primer cups, or poor rimfire heads. The light firing pin mark, by which the "hard primer" was judged, is more apt to be an inadequate firing pin blow. The shooter can very well rule hard metal out as a misfire cause.

Too light a priming pellet or a worn spinner lead to poorly filled rimfire cavities. Quality control routinely keeps control charts on pellet weight, to control both light and heavy pellets. Spinners are changed at prescribed intervals to insure against undue wear.

One thing over which the factory has no control outside is contamination by water or oil. Both "kill" the priming in short order. Water, a great aid to bathing and navigation, is anathema to a finished primer. A boon to safety in handling the priming mix in manufacture, water is the saving grace in making it possible to prime without using remote control. Once dry, however, the primer has to stay that way.

Although primers fit primer pockets tightly and bullets fit case necks almost as tight, long exposure to high humidity or water itself eventually dampens the priming. Moisture combined with heat speeds up the process. Oil, because of its increased capillary effect, may work even faster than water.

The rimfire bullet, crimped in place, has an extra turn down of lead over the crimp to improve the seal. Even so, the seal is far from being a totally effective defense against either water or oil.

Long storage under hot conditions may cause deterioration of the powder. Such powder gradually loses its strength, becomes somewhat more difficult to ignite, and the nitric oxide fumes from decomposition may also affect the priming.

The binder holding the mix together is, as discussed under the chapter on mixes, a gum. As such, it is subject, when wet, to bacterial action or even mold, which may weaken its binding action. Priming mix stored too long unrefrigerated may have lost the adhesiveness of its gum content, leading to an easily damaged pellet.

Under extremely unfavorable heat conditions over a period of time, it is possible for the powder itself to deteriorate to a point where the primer fails to ignite it. It might also be true that the primer has lost its zip.

The combination of the two could cause a condition called a "scorched powder" misfire. The powder shows evidence of partial ignition which failed to propagate itself.

I once investigated a misfire condition where some military .30-'06 ammunition had been stored outdoors in the bright sun under a dark tarpaulin for several years. The powder in the misfired cartridges was caked and fused into a lump by the primer's heat, but had failed to burn. This particular ammunition was being used in testing M1 rifles. Along with misfires, there were also reports of hangfires, low reports, and even bullets left in the barrels. All these were to be expected under the circumstances.

Rimfire cases, to be satisfactory, are very critical as regards the size and shape of the head cavity. It must be open enough to accept the largest particles of ground glass used in the mix, but must also be of a parallel sided "U" shape, so that the mix is compressed in, rather than squeezed out of, the cavity under the crushing action of the firing pin.

Along with cavity shape, the amount of mix used and the spinning thereof into the cavity become important. Too light a pellet and the cavity

doesn't get completely filled. Too heavy a pellet and the spinning action may be cushioned by the excess material.

It is common practice to keep track of pellet weights by means of quality control charts.

On rimfire, the normal pellet weight is in the neighborhood of .020 grams. Normal average weight of 10 pellets would range from about 0.019 to 0.022 grams. If individuals run heavier than 0.024 or lighter than 0.017, the lot would be held up for further check, and scrapped if further checks found individuals outside limits.

Centerfire pellet weights are likewise carefully checked and charted.

In the assembly of shotshell and centerfire primers, the space, called the "bridge," between the tip of the anvil and the inside of the priming cup must be very carefully maintained. If the bridge is too small, not enough of the mix may be crushed to start ignition. If too large, the blow may be overly cushioned.

The centerfire anvil, it will be noted, protrudes slightly above the bottom edge of the primer cup. This is deliberate. When the primer is properly seated, the legs of the anvil must, as a minimum, touch the bottom of the primer pocket. More properly, the anvil is pushed up a little deeper into the priming pellet. This slight compression of the priming mix increases the sensitivity of the primer.

Pocket depth and primer height are coordinated so that, when a primer is correctly seated, it is slightly below flush (about .002" to .006") with the base of the case. Failure to seat primers properly is a prominent cause of misfires in handloading.

Now we come to a final word on misfires—Chance.

There is a theoretical drop height ($\overline{H}$) calculated in primer testing. This is the height at which any one primer being tested has an equal chance of firing or not firing. As the drop height above $\overline{H}$ is increased, the chances of firing become better and better. Similarly, if the drop is decreased below $\overline{H}$, the chances of a primer not firing increases.

The more uniform the primers, the narrower the spread between the height at which all primers fire and the height at which none fire. From calculations of relative numbers of misfires, a statistical factor called "S" is developed as a measure of uniformity.

In rimfire ammunition, a good average for $\overline{H}$, using a 4 oz. drop weight, is 3-to 3½", and a good average for S is 1- to 1.25".

If we add 3 "S" 's to an $\overline{H}$ of 3½, we get a height of 7.25 inches. At this drop height, by chance alone, the odds of a misfire occuring change from the 50/50 at $\overline{H}$ to one in about 30,000. At $\overline{H}$ plus 2 S, the odds drop to about one in 3,000. A firearm in good condition strikes a blow about equivalent to a drop height of $\overline{H}$ plus 4 or 5 S. The odds, of a misfire due to random chance, then, are on the order of three in 1,000,000.

Firing pin shape is another important factor. The standard firing pin for centerfire, around which all sensitivity is checked, is one with a hemispherical tip of 0.10" diameter.

Some rimfire firearms use a similar hemispherical tip. It must be centered over the cavity in the rim. Too far out or too far in and the mix doesn't get well struck.

The majority of rimfire firearms use a chisel shaped firing pin point, again centered over the rim cavity. The standard point for drop testing, and a good one to use in firearms manufacture, is one tapering on a 25° included angle, with a flat on the end about 0.020" wide, and a breadth of about .060" so as to span the rim.

It may seem that a lot of words have been put down on the subject of misfires. It is the single largest complaint coming from the field. In my days on the Western complaint desk, misfires accounted for about half of all the rimfire squawks, 20% of the centerfire, and 18% of the shotshell complaints. Even so, the complaint frequency compared to the vast quantities of ammunition shipped was low, about 1 in 4½ million rimfire cartridges shipped. In more than half of these, the ammunition maker was not at fault.

Squibs

The two most serious of ammunition malfunctions are at opposite ends of the scale; high pressures and burst cases at one end, low pressures and squibs at the other.

A squib is a failure of a cartridge to reach its normal range of pressure. Severity may range from a low velocity round where bullet or shot charge barely leaves the barrel, to a shot which leaves a bullet or shot and wad still in the barrel. The last is the worst because a following shot will either put a ring bulge in the barrel, making it look like a snake which swallowed a bullfrog, or burst the barrel. With a burst, flying metal may injure either shooter or bystander.

A .22 rimfire rifle barrel seldom, if ever, bursts from a bullet left in the bore. A centerfire rifle can be expected to burst. A shotgun barrel will be no more than lightly ringed if at all with a wad remaining, but will almost always burst if both shot charge and wad are left in the bore for a following shot to strike.

With a shotgun the shot will roll out if the muzzle is lowered. The wad will remain. A duck hunter, shooting overhead and firing rapidly, might not recognize a squib, and would be the most likely to fire a following shot. He would be left with a severely damaged barrel.

All ammunition companies use great care in avoiding conditions which could lead to squibs.

Not all the conditions which cause squibs are within the control of the ammunition manufacturer.

Several conditions can lead to squibs:

- A very light powder charge.
- A very light priming charge.
- Incorrect powder—too slow.
- A very low bullet pull in rimfire.
- A very weak crimp in a shotshell.
- A damaged or inverted wad in a shotshell.
- A small diameter bullet in rimfire.
- A light shot charge in a shotshell.
- Powder contaminated by oil, lubricant, or water.
- In very old or poorly stored ammunition, deterioration of powder and priming.
- Extremely low temperatures.

A light powder charge may simply not be enough to move the bullet out of the barrel, or may do it at very low velocity. Also, with the extra space left in the shell, the powder may not be confined enough to burn well.

Light priming charges may not provide enough heat to ignite the powder well.

Too slow a powder may not meet resistance to build up its normal pressure.

In rimfire cartridge, a light crimp releases the bullet before the powder is properly ignited. A proper burn rate is then never reached. The same thing can occur with a very soft crimp and a slow-burning shotshell powder.

A mutilated or tipped shotshell wad allows too much gas leakage.

The most common contaminant in powder is oil. Capillary action lets oil creep past crimp, joint of bullet and case, or seal of primer in pocket. If the contamination goes on long enough, an outright misfire will occur. Short of that, the oil makes the powder hard to ignite and slows its burning rate, besides using up oxygen the powder needs.

Under conditions of high temperature and humidity, both powder and priming deteriorate more rapidly on storage. Advanced deterioration affects ignitability of both.

The factory continuously checks loading by cooling ammunition to $-40°$, and shooting it. Any tendency toward poor ignition will be brought out quickly at this temperature.

Burst Heads in Rimfire

The worst of all rimfire casualties is a burst case head (See Fig. 67). High pressure gas, escaping through the burst section, comes back through the firing pin hole and around the bolt, carrying with it small fragments of brass and burning powder. The magazine and stock may be damaged, the extractor blown out, and, worst of all, the shooter may be struck in the eye or on the face with brass fragments. The burst makes a loud bang close to the ears which is most unpleasant. Frequently, though not always, the bullet is left part way along the barrel by the sudden drop in pressure. With the bullet left in the barrel, a following shot will surely ring the barrel, producing a visible bulge. All of these things are bad. What causes a burst head? Some of the causes are:

- High pressure
- Heading defect
- Thin, soft brass
- Headspace
- Sharp chamber mouth
- Lack of head support
- Revolver design, as regards the cylinder
- Failure to fully close

The burst head may be complete, in that the head is entirely separated from the case, or the

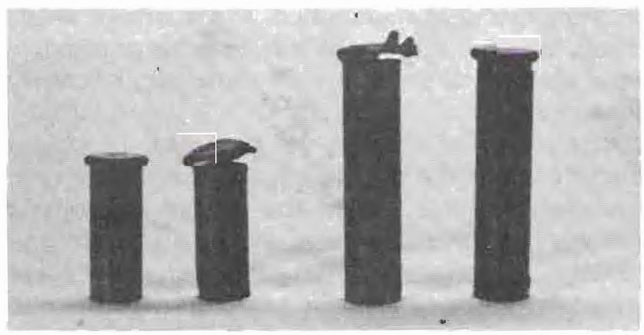


Figure 67: .22 Rimfire Burst Case Heads Probably Caused by Mechanical Defect in the Firearm

break may be partial, with only a portion of the head blown out.

Examination of the burst may give some clues as to cause. With excessive headspace, a complete separation will leave a short section of the case body in the chamber. Comparing this short section with the straight portion of an unfired case will show an obvious length difference. The burst under normal headspace would show a straight portion the same length as that of an unfired case.

Likewise, a partial burst from too much headspace will show a head of peculiar thickness, almost like a double head, and a short body section. These causes are easy to spot.

What has happened is that, as the pressure starts to rise, the case is forced back against the fact of the bolt, pulling the body of the case out of its full depth in the chamber. Brass is thinner in the case wall than in the head, and gives way as pressure rises to its maximum.

This burst is not the fault of the cartridge. In semi-automatic rifles, a failure of the bolt to fully close creates the effect of too much headspace. The symptoms are the same and the evidence will be plain to read. Failure to close fully is sometimes caused by mutilation of the case during feeding.

A rifle chamber must have its mouth rounded to a smooth, even if small, radius of .005″ to 0.10″. If the chamber mouth is left sharp or rough, the

case will shear against the sharp corner under pressure. This can be spotted on the burst case by the sharp corner showing at the point where the case burst.

Sometimes the extractor cut on the barrel chips out or gives way. This leaves the case unsupported at that point, and leads to bursts. Again evidence will show on the fired case.

If too much of the face of the bolt is cut away and corners are left dead sharp, the general effect is almost the same as that of too much head space. The head swells back where there is no support and shears against the sharp edges. This situation is one of degree, and assignment of cause is not clear cut. A cartridge on the high end of the normal range of pressure may burst on occasion, while those of slightly less pressure will stand the strain.

Recently a burst head complaint involving a revolver came into the plant here. This one had complications. The revolver could be fired (had been) without the cylinder being in line with the barrel. When fired, the bullet didn't have a clear path as a result. With the bullet held back by not being able to enter the barrel directly, pressure built up to where the case burst at the head. Matters were complicated by poor cylinder design. The cartridge heads were not recessed in the cylinder, but were exposed to each other. Thus, when the case burst, head fragments struck two adjoining cases, which also fired. These bullets found their way out far enough to release pressure, so that these heads did not burst. One bullet was jammed in the ejector along the barrel. The shooter must have been surprised, to say the least.

On the subject of recessed heads, in this case the manufacturer had simply recessed the entire end of the cylinder to a depth equal to head thickness, and then chambered. This, to a degree, would protect the shooter from a possible burst head, but, as shown above, didn't provide any protection for the other cartridges.

Speak of a burst head, and most shooters will instantly think of high pressure or too much powder. The foregoing causes were discussed first to emphasize that the causes aren't all that simple.

If the case bursts because it isn't strong enough to withstand the interior pressure, it can always be said that pressure is the cause. Going a step further, it could also be said that firing the cartridge was the cause. The question is whether the pressure was within normal limits.

If the factory stays within the SAAMI recommendations for rimfire pressures (a maximum product average of 26,000 CUP) fewer than 3 rounds in 2,000 should exceed an individual pressure of 30,100 C.U.P., and those will not be much greater than this figure.

With this limit in mind, the factory, in establishing its basic case design, checks its cases out at pressures considerably higher than 30,000 C.U.P., so that there is a reasonable safety factor to handle the possible few which might reach 30,000 C.U.P.

Then, in production, working pressure levels are kept at average well *below* the 26,000 maximum allowable average, providing additional assurance that the individual safe high pressure limit won't be exceeded. Checks of pressure during loading are conducted, at least once or twice per shift. In addition, powder charger limits are maintained by control chart. Lastly, the random selection and firing of at least one cartridge from each plate guards against any use of incorrect powder.

The net result is that pressures high enough to burst a normal cartridge case are extremely rare. No ammunition company wants to risk being charged with causing injury to its customers, hence the careful control.

Burst heads under normal pressure can occur, if the cartridge case is defective.

Most case defects causing bursts occur in heading. If the case metal is too thick, too thin or too hard, it may not bend correctly, creating a shear condition in the bend. This will show clearly in the shape of the burst portion (See Fig. 68).

Care must be taken in this area to maintain proper fit between heading die, heading inside punch, and case metal. If the fit is too tight, the case may be hardened by cold work as it is squeezed between punch and die on its way up to be headed. A tiny fold or shear will then occur on the underside of the head. This in turn will lead to a partial or complete head separation or burst on firing.

If the mouth of the die is too sharp, and there is no slack in the inside punch ram, the case may have metal sheared just under the head. Lack of support by the barrel in this area may lead to bursts. Too thin a case at this point will also create a shear at the bend. The thin metal bulges instead of bending sharply.

This sheared condition is not very noticeable on the burst case as a rule, but will show up on companion cartridges.

Leaky, Dropped and Blown Primers

As with rimfire, failure of the centerfire cartridge head to withstand pressure is a serious matter.

Figure 68: Burst Rimfire Case Probably Caused by Improper Heading

High pressures combined with low head hardness are mostly responsible for enlargement of the primer pocket. The primer pocket must be of uniform and proper diameter top to bottom to begin with, or occasional gas leaks around the primer are to be expected.

A small expansion in head diameter under pressure may allow a small amount of gas to leak past the primer. A larger increase may allow the primer to drop out of the pocket as the bolt is opened, and a further increase would allow the primer to be blown entirely out of the pocket.

Head hardness must therefore be controlled so that the elastic limit of the case is not exceeded by the pressure within.

As with rimfire, a manufacturer checks his centerfire cases at pressures much higher than working pressures, and adjusts case dimensions and base metal-thickness so as to get enough cold work in pocketing and heading to bring hardness up to the necessary level (See Fig. 69).

In production, cases are sectioned and hardness at various areas of the head is checked with a diamond point hardness tester.

Loading is controlled so that average working pressures do not exceed recognized standards, and so that individual pressures are kept well below case proof pressure.

In investigating a dropped or blown primer, the case itself provides the best clues. The head should be sectioned and hardness checked in the critical areas. It should be remembered that firing and the resulting movement of metal will increase hardness readings slightly. If hardness is substantially within specification or near to it, the cause for the dropped primer is most likely a high pressure.

There is, however, the possibility of lack of cartridge support at the breech end of the chamber. In many older rifles there is a fairly long gap between the end of the bolt and the mouth of the chamber. This gap is bridged by the cartridge case. Expansion in this area may lead to some expansion of the head.

Excess headspace is not a primary cause; it leads to a condition known as a cut-off, which occurs on the body of the case farther down the chamber. The case simply stretches in two, the head portion moving to the rear to the bolt face, the front portion moving forward. Little gas escapes to the rear. The jammed front half of the case presents a problem in removal. Putting the two pieces of case together will show a longer length than normal. An automatic or semi-automatic firearm in which the breech begins to open before chamber pressure has dropped, will create a cut-off. The effect is the same as that of excess headspace.

Figure 69: Centerfire Case Failure Probably Caused by a Soft Case Head

Pierced Primers

When a primer pierces, or is blanked out against the face of the bolt, there are several possible causes:

Lack of firing pin support
Too large a firing pin hole
A rough or improperly shaped firing pin tip
High pressure
Wrong primer

A firing pin that fires a primer on a high pressure cartridge should have a strong enough spring to give it good support against the primer under pressure. If not, the pressure inside the primer forces the primer back against the face of the bolt and it may blank out against the firing pin hole. The larger the firing pin hole, the more apt the primer to blank out against it. A blanked primer is one where the metal in the primer opposite the firing pin hole is sheared through the hole by the pressure inside.

The larger the firing pin, the greater area the pressure inside has to work against, and the more force will be exerted to cause blanking.

It's obvious that a sharp-pointed firing pin will cause a primer to pierce. What is generally not realized is that a rough firing pin tip may give the same trouble. If rough, the tip tends to carry the primer metal directly forward, whereas the metal should flow smoothly around the tip to create the indent. The result is sheared metal and a pierced primer. The hot primer and powder gases flowing past the tip erode it and make it still rougher, so that following shots are still more apt to pierce.

Metal used in pistol primers is thinner than that for rifle primers. The accidental substitution of small pistol primers for small rifle primers in a high intensity rifle cartridge such as the .223 Rem. is very apt to result in pierced primers. Likewise, large pistol primers will usually pierce in higher pressure rifle cartridges.

Accuracy Problems

In Chapters IX and XI, the various factors affecting accuracy were discussed. For the finest accuracy, obviously, all the variables must be controlled and extra controls cost money. On a day-to-day basis, the factory has only the problem of controlling accuracy within specified limits, and,

for economic reasons, must do so with a minimum of testing and checking. It is not the purpose of this section to repeat earlier observations on accuracy, but rather to show what a factory might do when the product fails to meet accuracy standards.

Standards are set for the product, whatever caliber, bullet type and weight, on some sort of a practical basis: ultimate accuracy versus cost, manufacturing process versus cost, and inspection and testing versus cost.

When a production lot of ammunition fails in accuracy, and previous lots have been okay, the factory first looks to see what might have changed, beginning with the bullet. In fact, most inaccuracy is caught when bullets are tested prior to being loaded in production.

Bullet inaccuracy is created by some or all of the following:

Side wall variation in bullet jacket—a prime factor in inaccuracy.
Poorly formed heel—wrong tooling or poor set up.
Too much sizing downward—the assembled bullet was made too much oversize in diameter prior to its final sizing. Excessive sizing leaves the jacket and core less than tightly bound together.
Wrong diameter—somebody used the wrong sizing die or a die became worn.
Upset in bore—too thin a jacket or too soft a jacket.

If the process has been fairly well under control, the degree of inaccuracy shouldn't be very great. The most common first step is to "rehit" the bullet. Bullets are run through the last forming stage again and resized again, if necessary. This step reworks both heel and jacket and core tightness. Generally, accuracy is improved. If not, a second rehit may be tried, but chances of success are small. If these steps don't work, generally there isn't much that can be done to salvage the lot.

Bullet lots are tested with other components of known quality in an accuracy barrel of known performance. If inaccuracy in testing the bullet lots occurs, it can normally be charged against the bullet.

If, later, with good bullets, poor accuracy shows up in production loading, then further cause has to be looked for in the loading operation:

1. Velocity variation due to: powder charge variation, powder choice, poor ignition due to powder or primer, or a damaged bullet. The bullet may be damaged in loading at the time of seating, or at crimping, so as to not fit the rifling properly.
2. Test equipment. One looks for a worn barrel or for metal fouling.

Barrels usually wear most at the throat, where the powder gases are at their highest temperature and pressure. As the throat wears, the bullet moves further and further down the barrel, picking up velocity before it finally meets the rifling. Under high pressure, the bullet may upset in the enlarged portion of the throat, to be resized in the tighter rifled section. Jump and upset both affect accuracy.

Leading or fouling mar the bullet as it passes over the fouling in the bore, making the bullet unsymmetrical. Lack of symmetry, again, causes inaccuracy.

So far as the case is concerned, usually in an established cartridge, the case has little or no effect on accuracy.

3. It is possible that the operator is using the wrong technique in shooting for accuracy.

Blowback

To many shooters, any escape of gas from the chamber to the rear in firing is a "blowback." In the factory, blowbacks are almost entirely limited to rimfire cartridges, and are entirely different from burst heads (See Fig. 70).

When a rimfire cartridge is fired, normally the quick build-up of pressure, helped by the crimp, causes the cartridge case to swell in the chamber, so that all the powder gas is occupied with pushing the bullet forward. This swelling and sealing carries the fancy title of "obturation," a good word for crossword puzzles.

If the pressure builds up too slowly, or the case is too stiff, gas starts expanding back along the outside of the case, preventing it from sealing off the chamber. When this happens, part of the powder gas escapes past the cartridge head and the bolt face. This is a blowback. The outside of the rimfire cartridge case under this condition will show a dark smudge of powder. There will sometimes be a loud bang, entirely different from the normal muzzle sound. The intensity of the bang is more or less proportionate to the severity of the blowback.

Badly worn chambers, greatly oversized, together with worn throats, aggravate the potential blowback condition, and may create blowbacks with entirely normal ammunition.

From Squires Bingham, ammunition is shipped to many different locales, some of which are well populated with well worn, hand-me-down rifles of dubious age and wear. On many of these the chambers are badly worn. It is, therefore, the usual

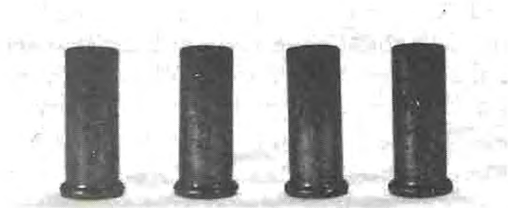


Figure 70: Smudged Cases Typical of "Blowback"

practice here to test fire all outgoing lots in rifles deliberately made with over-sized chambers (diameter .236" at the breech, .232" at the mouth of the case) as a check for potential blowbacks and to guard the customer against himself. Few shooters will bring themselves to admit their rifles are worn out. Rifles and chambers over-sized by six thousandths could under no circumstances be classed as being in good condition, and deserve mandatory retirement. But for sentimental reasons, economic reasons, and plain ignorance on the part of the shooter, retirement is probably not to be expected.

Hangfires

Hangfires are a symptom of poor ignition. The hammer is heard, or felt to fall. The explosion follows distinctly later—a click-bang. It is a common fallacy, however, to believe that a hangfire is a matter of several seconds or a minute or two. Actually, a long hangfire would be on the order of .1 second.

Shooters have on occasion claimed hangfires of a half minute or so, but in these cases the hang-up was probably in the hammer fall after the trigger was pulled.

The longest hangfire that I have personally witnessed was not in a shoulder-fired arm, but in an artillery piece. In the old 155 mm Schneider howitzer, the projectile and powder are separately loaded. The projectile is rammed into the chamber and a powder charge consisting of a base charge, which is a red colored bag, and up to six white bags tied together are placed in the chamber. The red bag is chambered last. The breech is closed and the priming cartridge is inserted in a small screw-in device separately. When the piece is fired, the primer ignites a charge, which in turn ignites the base charge in the red bag, and the base charge then ignites the main powder charge.

At a 155 mm howitzer battalion artillery practice at Camp McCoy, I was acting as a safety officer for F battery. Out of the corner of my eye, I saw one of the gunners in neighboring E Battery push the powder charge into the chamber, red bag first. I immediately yelled, "Cease-fire," but in the time that was available and the distance between the batteries, my "ceasefire" wasn't understood by E Battery. The breech of the piece banged shut, the primer was inserted, and the gun was fired as I watched. That was the longest hangfire I've ever witnessed. It must have been at least two seconds before the charge finally went off and when it did it was of low velocity and the round fell very short. Fortunately, no one was down range and there was no one injured.

Poor Patterns

With the advent of the modern plastic shot shell wad built with a pump-washer type base and a shot cup, individual poor patterns are almost a thing of the past. Still, with "economy" loads, pattern performance may not be all that might be desired.

Soft shot, other things being equal, deform more during firing, in spite of a shot cup and the shot spread out more in flight. A shot cup helps, if it is used. Conventional old style wads without cup will continue to be a possible cause of poor patterns. If the wadding is too hard, the shot will be damaged more due to their own inertia against the sudden starting shock. Gas leakage with old style wadding will, as usual, tend to cause balled shot and leading. Leading and balled shot make for poorer patterns.

Problems Cases

Cases, either centerfire or rimfire, will tend to split if the wall thickness on one side of the case is much greater or much less than that on the opposite side. The thicker side, being stronger, stretches but little and the weaker side takes most of the strain. If the elastic limit of the brass is exceeded, it will split (See Fig. 71). The elastic limit varies with case hardness. If a case is too soft it will stretch too much. A deep scratch has the effect of weakening the case at that point, again because of a change in thickness and a concentration of stress (See Fig. 72).

Mercury testing checks for potential splitting due to season cracking. The mercury attacks an area under strain faster than it does an unstressed area, and the weakened case will split in a matter of minutes.

On rimfire another split, a crack across the rim, is apt to occur, if the case is not relief annealed after heading. The case is subjected to sharp bending in two directions at heading, as well as stretching, and considerable stress is built up. The relief anneal is at a temperature (approximately 450° to 500°F) below the critical recrystallization temperature of brass. The effect of the lower temperature is to equalize the stress without softening the case, so that its strength is not lowered.

Other things can cause split cases, such things as defects in the metal, metal that is laminated, inclusion of foreign material in the metal, deep scratches from the dies which are not ironed out in subsequent draws, and, quite possibly, damage to the case by the loading machine as the cartridge is being loaded. All of these things have the effect of weakening the sidewall allowing stress to occur.

A recent problem in Manila brings out another cause of splits in centerfire. (See Fig. 73). A sample of .223 Rem. cases showed up with splits at the head extending a short distance up the sidewall. Hardness was okay, brass thickness in the sidewall was okay. There were no draw scratches on the outside of the case. Diameter was within tolerance.

On sectioning a case, the cause became obvious.

Figure 71

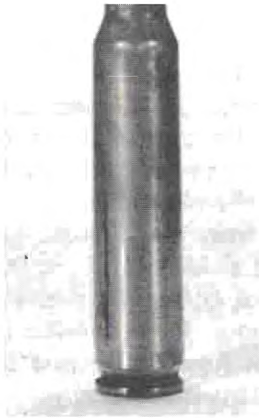


Figure 72

Figure 73

Samples of Centerfire Case Failures Caused by Manufacturing Faults

During head turning, the pusher that shoves the trimmed case out of the holder was striking the inside of the head off center. The pusher moves rapidly, and the case fits quite tightly in the die. The off-center blow dented the head, thinning the metal and hardening it so that a stress point was set up. At firing the strain caused the case to split precisely at that point. This is a bad defect, considered major by the military. The split at the rear of the case lets gas almost directly back around the bolt.

Bullet Failures

One consumer complaint that is of some concern, because quite a bit of correspondence does go back and forth on the subject, is that of bullet upset.

The hunter is unhappy because:

1. The bullet went on through the animal.
2. The bullet didn't go through the animal.
3. The bullet didn't open up enough.
4. The bullet opened up too much.
5. Jacket and core didn't stay together.

It would seem that the customer would have the best of both worlds if a core went on through and the jacket didn't, but there doesn't seem to be much happiness when this happens. About the only thing that is agreed on among shooters is that the core and jacket should stay together.

Depending on the hunter, the game, and the range, the same bullet could fall into any one of the five categories above.

Unless some special design is used to tie core and jacket together, under some conditions of upset separation will occur. The manufacturer should determine what is for him satisfactory upset at a range that suits his customers. He should then check by shooting into water at a velocity corresponding to that range. The design may be later modified so that there is a balance in both directions. A study of existing bullets in the marketplace will produce enough data and design to let a new bullet maker work out a satisfactory set of compromises.

Oil

A visitor came in one day, a policeman, wearing a sheepish expression and carrying a revolver that didn't work. The gun was a Model 1917 Smith & Wesson .45 ACP.

The barrel was bulged like a snake on a diet of goose eggs. A bullet had its nose peeping out the muzzle, and the cylinder wouldn't turn. After unscrewing the barrel, we found it completely full of bullets. The last shot had stayed partially in the cylinder, jamming it.

Somebody, it seems, had called the police station, asking to have an old horse shot. The desk sergeant had detailed my visitor for the job. He'd said, "No thanks," but lost the argument, and had gone out to do his sworn duty.

The horse was standing in a barn, munching hay. Reluctantly, the officer drew his revolver and aimed it at the horse's head. Then, unable to look the horse in the eye, the executioner turned his head and pulled the trigger.

Looking back, he found the horse still munching hay. Maybe he'd missed. Bang! went the second shot, no better. So went the other four shots. Stubborn man, stubborn horse. Into the cylinder went six more rounds. Two more shots and the gun jammed. Without even a horse laugh, the horse went on eating hay. The mission was abandoned when the officer found the bullet sticking out of the muzzle.

The cause was a slight case of oil. The ammunition was a long way from fresh and had been in the cylinder, well oiled, for years. Enough oil had crept between bullet and case to foul the powder, but not the primer. Enough powder had burned to start the first bullet down the barrel. Subsequent

shots pushed it along. Some shots were strong enough to make bulges, some weren't.

Moral: Even oil-proofed cartridges may give up the ghost eventually under attack by light oils or gun cleaning solvents.

At the risk of being accused of self-interest, being in the ammunition business, I would think it wise for every law officer to do a little target practice with his ammunition every six months and replace it with new.

Self-loading Shotguns

The most troublesome combination of gun and ammunition is the automatic shotgun and shotshell. Light loads, heavy loads, paper shells, plastic shells, fast powders, slow powders, and reloads, anything that goes bang, all are supposed to make the gun work properly. Not the least of the problem is that individual guns of the same make don't all function alike. Most semi-auto shotguns' malfunctions have to do with ejection and feeding. Some guns, open before chamber pressure has dropped and pull the heads off shells.

The Browning recoil operated automatic had a reversible friction ring, for light loads or heavy loads, on the barrel guide that slid along the magazine tube. It helped, but wasn't an absolute cure.

In the midst of such a confusion of loads and guns, determining fault in a given case is not always easy, nor is the answer always clear-cut.

The gun maker tests his design with a broad assortment of loads. The ammunition maker tests his shotshells in a fair number of different makes of shotguns, some worn, some new. In the final definitive test by the public, what works well in the factory may do much differently in the customers' hands.

When the Model 50 Winchester shotgun was first introduced, each of the first few shipped had been fired a hundred rounds with both light and heavy loads of mixed manufacture, without malfunction.

Two customers reported jams in the first 25 rounds fired.

The next 1,000 guns that went out had been fired with 100 rounds of mixed ammunition, again with no malfunctions. Some of these didn't work perfectly either.

My personal Model 50 was assembled almost entirely from parts that had been rejected for one reason or another. I fired that gun more than 5,000 rounds at skeet, and at least another thousand or so at ducks down on Long Island Sound, and never had a malfunction.

Earlier, in the chapter on powder, we mentioned the slight change in powder speed C.I.L. made with their 12-ga. Red Dot loading for skeet, where Model 50 performance was affected. In the Model 50 a small change in power stroke improved the general functioning level very early in production.

The public has a genius for ferreting out bugs unknown to the factory shooter, who may unconsciously favor the gun and ammunition. Most automatics work better when firmly held against recoil. Some of the older shooters, tiring of recoil, used to shoot from the hands, tossing the gun slightly forward at each shot. Such an action provides more than enough resistance to recoil, favoring functioning. Orders were issued that automatic shotgun function testing had to be from the shoulder. This should apply equally to ammunition and gun testing.

The answer to the public's ability to find new and different problems with guns may literally be to drag some new, inexperienced shooters off the streets to test new products, as well as some production items. Training of such people should be minimal, except for safety. Shooting results should be carefully observed.

As a rule, the functioning problem lies more with the gun than the ammunition. Which brings to mind a succinct letter Winchester once received from a Model 40 owner. Among other things, the M40 automatic 12-ga. had a bad habit of separating magazine tube from receiver. The model didn't stay on the market for very long. The letter, reprinted verbatim, follows.

> Winchester Arms Mfg. Co.
> New Haven, Conn.
> Dear Sirs:
>
> I have one of your goddam model 40 shot guns and the other day when I shot at briar rabbit it go bang-bang when it should have only banged. The pieces are now assembled in my derby hat. Since I need my derby hat comes New Years, please advise disposition.
>
> In the mean time I'll have to use a piss-elm club and besides my wife wont let me use guns that blow up.
>
> Very truly yours,

Bullets in Barrels

A bullet left in a barrel is best removed by pushing it out with a ramrod, which should fit the bore fairly closely. Simple. There is a harder way. One of the first of the several thousand complaints that crossed my desk for adjustment after I moved to the Ammunition Sales Department showed how.

A teenager brought in the remains of his rifle, a bolt-action .22 rimfire, its stock shattered at the receiver, extractor missing, and magazine bulged. The remains of a burst cartridge case were still in the chamber. He was rather badly shaken, but only slightly damaged.

According to the youngster, he'd found part of a box of old .22 ammunition. One round had gone "poof" and left the bullet in the barrel. Somewhere he'd heard that the best way to get the bullet out was to remove the bullet from another cartridge, dump out half the powder, then load the half-charged case into the chamber and shoot it.

He did so, pointed the rifle at the ground and pulled the trigger. Nothing happened. Several more attempts produced no results. A final trial produced the devastation. Each time the rifle was pointed down, the powder charge ran down the barrel, too far for the primer flash to reach. As the pile of powder built up, it finally connected with the flash, and a whole lot of half charges went into business.

The stuck bullet definitely left the barrel.

Although the company wasn't responsible, the boy got a new Winchester rifle, because he'd been honest in telling what he'd done. The new rifle didn't cost much, and we made a lifelong customer.

General Hatcher, in *Hatcher's Notebook*, mentions also that a half charge of powder in a .30-'06 rifle will remove a stuck bullet. He certainly didn't include pointing the rifle down so that the powder could run out of the case.

Damaged Guns

One of the things that causes unhappiness among customers is the occasional blown-up gun or gun barrel. The ammunition company, as a general rule, seems to get blamed for the trouble. However, from an analysis of a good many burst gun complaints, it is quite obvious that the ammunition company is seldom the culprit. Of course, there are some incidents that can't be really classified as to cause. Most cases, however, are clear cut.

For quite a few years after World War I, a number of burst rifles came in from people who had shot 8mm Mauser and Mannlicher cartridges in 30-'06 rifles, mostly Springfields.

To the casual observer, 8mm and .30-'06 cartridges look alike, although there is considerable difference between them. The Mauser bullet is .323" in diameter, while that of the .30-'06 is .308". The shorter 8mm case can be made to fit in the Springfield chamber, as well as that of other .30-'06 rifles. The Springfield is mentioned specifically because it was the rifle most often sent in.

When an 8mm Mauser cartridge is fired in a Springfield chamber, the results are quite uniformly bad. The receiver is broken, so that the serial number on the receiver ring is generally missing. The face of the bolt is apt to be chipped around the extractor groove, where it is the weakest. The barrel is split for 10 to 12 inches from the breech. The bullet is usually found about 16 to 18 inches down the barrel. With this evidence in hand the answer is plain. The bullet will have the core squeezed out from the reduced diameter jacket. The bullet weight is not the usual 150-, 180-, or 220-gr, but 170-, 200-, or 226-grains, depending on the 8mm load.

The head of the cartridge, although badly mutilated and expanded by the pressure, may have enough of the headstamp showing to indicate something other than .30-'06. On commercial ammunition an "8" or an "mm" is a dead giveaway. A military headstamp is also obvious.

The same accident can happen with other calibers in wrong chambers, but doesn't show up very often. One incident I do remember didn't result in a burst gun, but did result in a very hard opening of the bolt. This happened on a hunt that Jack Boone, who was sales manager of Winchester-Western, and I had on Gardner's Island, through the courtesy of Joe Gale, who was proprietor at the time. We went over to help reduce the deer herd, which was eating itself out of its habitat.

I took along one of the then new Model 70 Featherweights in .308 Win. and Jack took a Model 70, .270 Win. Somewhere along the line Jack got one of my .308's in his pocket and without knowing it, loaded it in his .270. It will be remembered that case diameter at the rear is the same for both calibers. The .308 Win. case is enough shorter than the .270 that it will chamber in spite of the larger diameter bullet.

Jack fired the rifle once, to checking his zero, and was not able to open the bolt. By repeatedly banging the bolt handle against the top of a fence post, we finally beat the action open and the cartridge case came out, primer pocket and head badly swollen. The answer was on the head of the case, it very clearly said .308 Win.

The following Monday, when I went back to the plant, I immediately called Dick Morgan, who was in charge of Firearms Quality Control. Dick went over to warn the shooters in the function firing and targeting area that it was possible to shoot a .308 in a .270 chamber. Both calibers were going through the function bank at the same time. Dick came back in about 20 minutes and said that most of the shooters had already managed to make the same mistake. Embarrassed, they hadn't seen fit to mention the matter.

One of the common bad accidents that use to show up, and probably still does but with less frequency through education, is what is commonly known as the "12-ga./20-ga. burst". To one who has seen several of these instances, the trouble can be spotted across a fairly large room. The evidence is plain, follows a very definite pattern, and is easy to diagnose.

What happens is that a 20-ga. shell gets dropped into a 12-ga. chamber by accident. The shell slides forward until its rim stops against the forcing cone.

Seeing the chamber empty or getting a click when the trigger is pulled, the shooter puts a 12-ga. shell in the chamber, in back of the 20-ga. shell. When the gun is fired the barrel, with few exceptions, bursts just at the point where the 20-ga. shell was lodged. Depending on where the shooter has his hand, there is injury to forefingers, thumb or forearm. The few exceptions to bursting seem to occur when the 20-ga. shell fails to fire. Even so in most barrels there will be some sort of bulge.

The break will clearly show two things. On the portion of the break where the head of the 20-ga. shell was lying, there will be a brass wash on the fractured steel. Ahead of that, where the paper, or with today's ammunition, plastic, tube lay, there will be small bits of paper or plastic embedded in the fracture.

On one occasion, I was able to even say that the 20-ga. shell was of a competitive brand. The knurl around the head was of the old distinctive Peters pattern, and had left its mark on the surface of the steel in the barrel. Further, there was purple-colored paper in the break.

The same thing can happen with a 28-ga. shell in a 20-ga. barrel. I had checked this possibility out at one time and found that it could be done. Since 28-ga. shells are not particularly common, I didn't really expect to see such a case. However, one day a Model 21, 20-ga. came in from down in High Point, N.C. The barrel was not burst, but it was bulged just ahead of the chamber. Careful examination of the gun showed no other reason for the bulge, leaving the 28-ga. shell as the main possibility.

Checking the records, I learned that High Point has an active trap and skeet club. Anyone owning a Model 21 is pretty apt to belong to the local club. Taking a gamble I wrote the man and suggested that possibly he was a skeet shooter and might have had a 28-ga. shell in his pocket when he went hunting. It was the only explanation we could give to account for his bulged barrel.

The man immediately wrote back saying, "yes", he was a skeet shooter, "yes", he had a 28-ga. gun. He agreed this was the most likely answer, which closed the matter. He paid for a new barrel. An honest man.

Two other damaged gun complaints occasionally show up. One is a simple burst head, which damages the firearm, possibly by splitting the stock, blowing out the extractor, or bulging the magazine, or more serious damage. The other instance comes from a squib where a bullet or a shot charge is left in the barrel and is struck by a following bullet or shot charge. In these cases, the barrel is generally blown open, if it is a centerfire or shotshell, or bulged if it is a rimfire.

One personal injury suit that Winchester unfortunately, and I think, unfairly, lost resulted from an incident out West, quite a few years ago. A man bought a Model 70 Winchester in, if I remember correctly, .300 H&H Mag. caliber. He took the rifle to a private gunsmith, who removed the Winchester barrel, put on a barrel of his own, chambered it for a much larger capacity wildcat cartridge, restocked the rifle, and sent it back to the man together with a recommendation as to the maximum powder charge and bullet weight that could be used. The man admittedly loaded an even heavier charge in the firearm and blew it up, damaging himself in the process.

He sued Winchester on the basis that the action should have stood the pressure, even though it was not the original barrel, had not been proof tested with cartridges of the type he was using, and even though the powder charge was excessive. The company rightly refused to settle, as it should have, and the case came to trial.

At the trial, a local locksmith-gunsmith testified that he thought the steel in the receiver was too fine grained, and that it undoubtedly was not strong enough. In spite of the testimony of expert witnessses including a metallurgist on the other side, the jury believed the locksmith and the company lost the case.

On shotshell squibs, the story is a little different. Over the years, a great many letters came in so closely resembling each other that they almost might have been written by the same individual. The letter starts out essentially like this: "I am sending you my shotgun, which blew up with your ammunition. My friend and I were out on my back porch (or some similar place) and I took the gun out of its case and looked down the barrel and showed it to my friend and remarked how clean and shiny it was inside, and I assembled the gun and put one round in and fired and, lo and behold, the gun burst."

The gun which comes in has a burst somewhere down the barrel, which shows clear evidences of lead in the fractured metal. In some cases even a bit of wadding clings to the rough edges. Further, the barrel shows a distinct ring-like bulge at the location of the burst, definitely indicating a heavy obstruction.

It is a fact well known to the ammunition companies and generally quite well known to the shooting world that, if a gun is going to burst from high pressure, it will burst at the breech long before it will burst down the barrel because of the rapid drop in pressure as the charge goes down the barrel. Further, it has been well established over the years that an obstruction down the barrel heavy enough to cause a burst is generally either a shot charge or a bullet. A simple wad is not heavy enough. In this regard, I might refer the reader to a good publication "Smokeless Shotgun Powders" put out by DuPont a great many years ago, written

by the late Wallace H. Coxe who was a ballistic engineer in the Burnside Laboratory. Coxe covered the subject in several pages of the book, discussing 20-ga. bursts and high pressure bursts, as well as obstructional bursts. According to Coxe, obstructional bursts are the cause of practically 95% of all gun accidents. His statement pretty well agrees with my own findings.

Now, as to what causes a squib or the obstruction in the barrel is, of course, the main question in the company's mind. Of course, the shooter who says he looked through the barrel and found it bright and fired one round and the barrel burst has lost any credence at all in his story. A barrel simply does not bulge and burst down the bore without an obstruction. If the man had told the truth, he probably would have had his complaint received with a little more compassion. It would seem most likely that the man was ashamed to admit that he had fired the gun after having a squib of some sort.

The causes of squibs in ammunition were discussed earlier in this chapter. A squib on ammunition which has been away from the factory a long time, of course, is likely due to outside causes—dampness, oil, age, and similar things.

In a good shotgun barrel, a simpler light obstruction, like a wad, does not ordinarily leave a ring, nor will a small amount of snow, for instance. Mud may be heavy enough that a heavy slug at the muzzle will cause some bulging and with a very light choke maybe a burst. Putting the muzzle of a gun under water and pulling the trigger is quite apt to cause a burst, because the water is heavy, has a fair amount of resistance, and the hydrostatic pressure exerted on the barrel is more than the barrel can stand.

One year as I arrived at the Grand I was met by one of the Winchester-Western salesmen together with Jim Holderman, a trapshooter of some note. Jim was bearing a still warm over-under of a prominent make. The lower barrel had burst open on its underside just forward of the end of the forearm. In spite of the burst, Jim said he had broken the bird, and had also broken his bird on the previous shot. Recoil, he said, was normal. These things ruled out the possibility of squib obstruction. Further, sighting along the barrel showed no "ring" bulge in the vicinity of the burst. The barrel had apparently simply opened up. The gun was left with us to take back to the factory for closer examination.

In a few minutes, Jim was back. He remembered something. Ordinarily he hooked his finger over the end of the forearm when shooting. Two or three shots before the burst something had stung his finger, and he had pulled his hand back on the forearm on the following shots. As it turned out this had saved his finger, which he then offered for inspection in its unwashed state. There was a heavy black smudge left by escaping powder gas on the upper inside of the finger.

The barrel was very thin at the point of the burst and had developed a progressive small split which had finally given way entirely. An unusual case. The lack of a ring bulge was a definite clue, clinched by the burnt finger.

Very few bursts occur with centerfire rifle ammunition, probably because squibs are exeedingly rare and very few other things leave bullets in the barrel. On a rimfire cartridge, a burst head will leave a bullet in the barrel most of the time. If a following cartridge is fired without the barrel being cleared, there will be a ring at the point where the bullet was lodged. This, incidentally, will not cause a burst head, because the pressure, by the time the bullet has reached the obstruction in the barrel, is far below the bursting limit of the case.

CHAPTER XI
ACCURACY

It's a good bet that almost since the invention of firearms a search for better accuracy has been underway.

After the novelty of seeing and hearing the flash, smoke, and bang of the early hand cannon wore off, the idea soon came that hurling a charge of stones with powder could do more if the flight could be predictably directed. Sights and various gun mounts, including stocks, were added to help in holding and aiming, but the cannon or rifle ball had a frequent tendency not to follow the line of sight as expected. So the search for accuracy began.

Early expedients didn't work out, but the style of warfare helped make the firearm useful on the battlefield. Traditionally, troops on both sides were massed so as to be under direct vocal and visual control of their commanders. Firing an inaccurate firearm in the direction of the opposing mass was apt to produce chance impersonal casualties, at least. Battle then became a combination of fast reloading and "chicken." The side which could stand the casualty rate the longest without flinching or breaking and running won the battle. Tough on the troops.

It took some 400 years to develop the rifled barrel, and now, 200 or so years beyond that, troops no longer need to be massed to produce casualties. Accuracy has come a long way. It wasn't the military, however, who led the search for better accuracy and who took early advantage of the gains. It was the sportsman.

The rifled barrel, of course, made the first really big stride toward better accuracy, and might have had more effect on warfare earlier, if military commanders hadn't been so reluctant to gamble on it. The gunsmith and his customers weren't so reluctant and pushed the development.

With the rifled tube in use, long experimentation, competition, and hunting brought the blackpowder rifle to a peak in accuracy. Powder and ball, bore fouling, patching, and all the other things attendant to the blackpowder game, however, limited progress toward the ultimate one-hole group at long range. Still, some very good accuracy was and is possible with muzzle-loaders.

Smokeless powder, jacketed bullets, and the cartridge case with primer changed the system, and made new goals possible. Today's bench rest shooters have narrowed the gap between perfection and practicality to a remarkable degree. There isn't much room to get much better at the top, but lesser shooters can follow along, trying for those ½ minute of angle (m.o.a.) groups at 300, with a good chance of getting somewhere close.

An ammunition factory, on a day to day basis, checks accuracy on its finished product, seeking results that are satisfactory to the fairly critical user of the product, but making no determined effort to duplicate the very small groups shot by the bench rest shooter. Cost is the reason.

Economics of manufacture and practical usage dictate that hunting cartridges—and their attendant rifles—need to produce reasonable but not top notch accuracy. Bolt-actions lean toward the 2" extreme spread, 100 yd., level, with some doing considerably better. In most hunting combinations, rifles, light of barrel and factory bedded, cause more than half of the total extreme spread in a group.

The .30-30 W.C.F. is a good example. The accuracy of .30-30 W.C.F. hunting ammunition, as checked in the traditional "Mann" type of heavy barrel in a V mount, frequently averages close to 1" for 10 shot groups at 100 yds. Sometimes it does better. Fair averages for the same ammunition fired in lever-action rifles as they come from the factory would be 3½" to 5".

In this case, producing a cartridge that will average well under an inch extreme spread in an accuracy barrel wouldn't change the field result enough to be noticeable to any but the most exacting shooter, and then only after extensive testing.

I may be getting a little off the path here in bringing the firearm into the picture when discussing bullet accuracy, but, one isn't much good without the other.

In the factory, a rifle or pistol is seldom the vehicle of choice for testing ammunition accuracy. The test barrel, in interior dimensions, represents what the shooter is apt to tote to field or range. Bore and groove, chamber and throat, and head space are standard. The exterior of the heavy barrel usually fits some sort of heavy solid rest. Most common is the "Mann" rest, a heavy V block installed on a solid base. A very heavy barrel with action installed rests in the V, free to move under recoil. The V is adjustable for both windage and elevation. Each group is fired without changing adjustments. The heavy barrel minimizes vibrational effects.

This works fine for centerfire or ordinary rimfire ammunition. In one special case, however, actual rifles are used by at least one ammunition maker.

.22 rimfire match ammunition is that special case, and for reasons to be discussed later.

It is far easier to discuss what causes inaccuracy, than to tell what causes accuracy. Once the causes for inaccuracy are known, a search for corrective measures should lead to increased accuracy. Unavoidably, all corrective measures won't be 100% successful, and just maybe all the causes of inaccuracy aren't completely defined even yet.

The final result will inevitably fall short of perfection—a bullet-size, one hole group.

Interior and Exit Effects

Granted shooter performance has been perfect, what are the causes of inaccuracy? There are two principal categories: (1) things which happen with, and in, the rifle up to the time the bullet clears the muzzle and (2) random displacement of the bullet in flight.

Under (1) comes, as most people would guess, variation in muzzle velocity. If the bullet comes out of their rifle at a higher velocity than expected, it gets to the target quicker and doesn't drop as much, striking higher. Conversely, a lower velocity hits lower on the target. Vertical dispersion is affected, but not horizontal; at least not directly, as will be discussed later under wind drift.

As to the effect of muzzle velocity differences, consider the following two cases:

(1) Let's assume that we shoot 10, .22 Long Rifle bullets, each of 40 grs. weight, at an average muzzle velocity of 1250 f.p.s. Assume that the lowest velocity among the 10 rounds was 1200 f.p.s. and the fastest was 1300 f.p.s. By the time those two bullets have traveled 100 yds, their respective remaining velocities are 1015 f.p.s. and 1050 f.p.s. Their average velocities, over the 100 yards, are approximately 1095 f.p.s. and 1155 f.p.s.

Since these are average velocities over 100 yards, the time of flight is computed by dividing the range (300 ft), by the velocity.

Maximum time of flight	.274 second
Minimum " " "	.260 "

Going a step farther, the distance the bullet drops from a bore reasonably level is related to square of the time of flight by the formula:

Drop = $\frac{1}{2}gt^2$, "g" being the acceleration due to the effect of gravity, 32.2 feet per second per second. $\frac{1}{2}g$ expressed in inches is (12) × (32.2 ÷ 2) or 193.2 inches per second per second. T^2 is the time of flight multiplied by itself.

Applying the formula, the corresponding drops for the .22 LR are:

Maximum	14.50 inches
Minimum	13.06 "

Therefore, the vertical spread due to velocity difference alone could amount to 14.50 minus 13.06 or 1.44 inches.

Now for case (2) take a series of 50-gr. .222 Rem. bullets starting at an average 3200 f.p.s. with the same 100 f.p.s. velocity spread—highest 3250 f.p.s., lowest 3150 f.p.s. Corresponding high and low 100-yd remaining velocities, depending on bullet shape, are 2730 f.p.s. and 2650 f.p.s. Average velocities over the 100 yds are approximately 2900 f.p.s. and 2990 f.p.s. These work out to times of flight and drops as follows:

Maximum time of flight	.1035 second
Minimum time of flight	.1003 second
Maximum drop	2.07 inches
Minimum drop	1.95 inches

With the drop being proportional to the square of the time of flight, it can be seen that the higher velocity .222 Rem. bullet is affected much less than the .22 LR by the same velocity spread. The velocity spread with the .222 causes a potential vertical spread of only .12".

The effect of velocity variation isn't all that simple either. Depending on a great many things, not all due to nerves and heart beat on the part of the shooter, the muzzle is moving when the bullet exits. Vibrating, to be more precise.

Barrel vibration or flip may have a far more important effect than velocity differences on verticals. Spread is affected in two ways. One by the displacement of the muzzle from the sighted or intended line of flight at the moment of bullet exit. The second by the velocity, upward or downward, given the bullet at the moment of exit by barrel vibration or motion.

If the barrel is moving upward at bullet exit, the bullet is given an upward velocity, making it strike higher on the target than might be predicted. A downward movement works in reverse.

Vibration may not be all bad. It can sometimes compensate. For example, if the timing is such that the barrel is moving up when a low velocity bullet leaves, and down when a high velocity round leaves, the two may to a degree compensate each other. Very nice, if it works.

No reasonable barrel or bedding combination can ever be made stiff enough to eliminate all vibration. With the snap of the hammer fall, followed by the more violent primer fire, then the turmoil of the ignition and burning powder in the case, vibration starts. Then add the bullet's leap from case into rifling, the twitch of the sudden rotation of the bullet, and the ultimate bullet acceleration down the tube. All contribute to vibration.

The barrel doesn't necessarily vibrate straight up and down either. There may be some sideways movement, adding to horizontal dispersion.

So the muzzle is in motion, mostly up and down, at bullet exit. Measurement of magnitude and

	Time of Flight	Drop
High velocity bullet	.100 second	1.94 inches
Low velocity bullet	.103	2.05

velocity of this motion for analysis is not easy. It has, however, been done. Again, the oscilloscope helped in one study made.

Using a variable reluctance rig somewhat along the same principle as the cartridge in a hi-fi pick-up, and an oscilloscope, together with a time reference, some very usable data were developed. Photographs of the curves which appeared on the tube were analyzed. The amplitude of the barrel vibration at the muzzle was found to be about .0004", and the velocity of the muzzle motion was about 12 inches per second at the maximum.

This study was done using a light barrel the vibration characteristics of which could be expected to be more pronounced than those of a heavy barrel.

To a degree, a vibrating barrel follows the usual patterns of harmonic motion. Further experimental work indicated that the barrel vibrated with loops and nodes, as any steel bar might when struck.

A node is a point of no movement, as opposed to a loop which has maximum movement. In this case, the light rifle barrel tested had a node some $3\frac{1}{2}$" from the muzzle.

Back to high school geometry. Starting from a node, we can visualize a triangle which has two sides of $3\frac{1}{2}$", representing the muzzle end of the barrel at its farthest up and down movement. The third side is .0004", representing the amount of vibration.

By proportion, extending the $3\frac{1}{2}$" sides to 100 yds, the third side becomes .41". This would be the maximum effect, due to barrel displacement alone, that would occur if one bullet emerged as the barrel was at its maximum upward flip, and a following bullet emerged as the barrel was at its maximum downward movement. These two things don't necessarily happen in every series of 10 shots, but they could.

There is some solace. Velocity variations change the relative position of the barrel at bullet exit. The barrel, like any vibrating rod, tends to vibrate in some fairly uniform frequency and pattern. Any bullet emerging from the muzzle does so at a random location in the barrel's swing. This being so, only by chance will the barrel be at its maximum upward or downward displacement on any one shot. Therefore, the chances are reasonably good that in a normal 5- or 10-shot group, the maximum dispersion due to barrel displacement will not occur.

So long as the amplitude of the vibration stays the same from shot to shot, the effect on accuracy will be less than the theoretical maximum. Practical experiments show that the amplitude's effect is generally so small that it is less than the experimental error in trying to measure it.

Now consider the effect of flip velocity or muzzle movement on the bullet. The figure mentioned earlier in a light barrelled rifle was 12 inches per second. The bullet at exit is given some part of this velocity, either upward or downward, in addition to its forward velocity.

The amount of upward or downward velocity given the bullet depends on what the barrel is doing when the bullet exits. If the barrel movement is changing from up to down, or from down to up, the vertical velocity given the bullet is zero. If the barrel is crossing the midpoint in its swing, the velocity is maximum up or down, depending on which direction the barrel is moving.

Note that an emergence at midpoint cancels the effect of barrel displacement. With emergence occurring at exactly maximum displacement, up or down, there is no upward or downward velocity.

On its way to the target, the bullet loses virtually none of its lateral up or down velocity. Therefore, displacement at the target is proportional to lateral velocity times the time of flight.

If, as indicated earlier, the average time of flight of a 22 LR bullet over 100 yds. is .265 seconds, the displacement of a bullet moving upwards at 12 inches per second is 3.18". The same for a downward velocity, a total possible of 6.36". Again, it is to be expected that maximum upward and maximum downward velocities will not usually occur in every 10 shot group.

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The above, if nothing else, is a good argument for the heavier barrel for better accuracy. Less vibration occurs due at least in part to the greater inertia of the added barrel weight, as well as to greater stiffness. Little things affect the heavy barrel but very little, and bigger things affect it less than they would a sporting weight barrel.

In the 1930's, in East Alton, a careful study was made of the relative drops at 100 yds., of .22 cal. bullets fired from a heavy-barrel Model 52 Winchester at various velocities. The study showed that in the instrumental velocity range of 1100 to 1300 f.p.s. there was very little change in the total amount of drop with variations in velocity. Above 1300 and below 1100 ft./sec., drop *vs.* velocity seemed to correlate in following the Drop Law, where $D = \frac{1}{2}gt^2$ (See Fig. 74).

Relative drop simplified measurement. The rifle was aimed at an aiming point above the points of

impact. Drop from the aiming point was measured for each velocity level.

It was concluded at that time that barrel vibration was the most likely factor affecting relative drop. The test didn't have today's advantage of being able to measure each individual velocity over the 100-yd. range so that drop *vs.* velocity could be recorded for each shot. Groups had to be shot with cartridges loaded to various ranges of velocities. Nevertheless, the fact that the curve drawn from the firing data showed a definite plateau in drop became a principal factor in establishing a favorable match cartridge velocity for what was then Western's new .22 Super-Match Mark II.

Years later the same test was repeated with modern instrumentation and over a wider range of individually measured velocities. The newer results only refined those from the earlier test; there was no basic change in the drop curve.

The much smaller effect that velocity variation has on high velocity bullets may make a similar test of limited value. Still, all rifle barrels do vibrate, and it may be that individual high velocity rifles do have optimum velocity levels for best accuracy with particular bullets.

In-Flight Effects

After the bullet leaves the muzzle with its path set, so far as the effects of varying velocity and barrel movement are concerned, the in-flight effects take over.

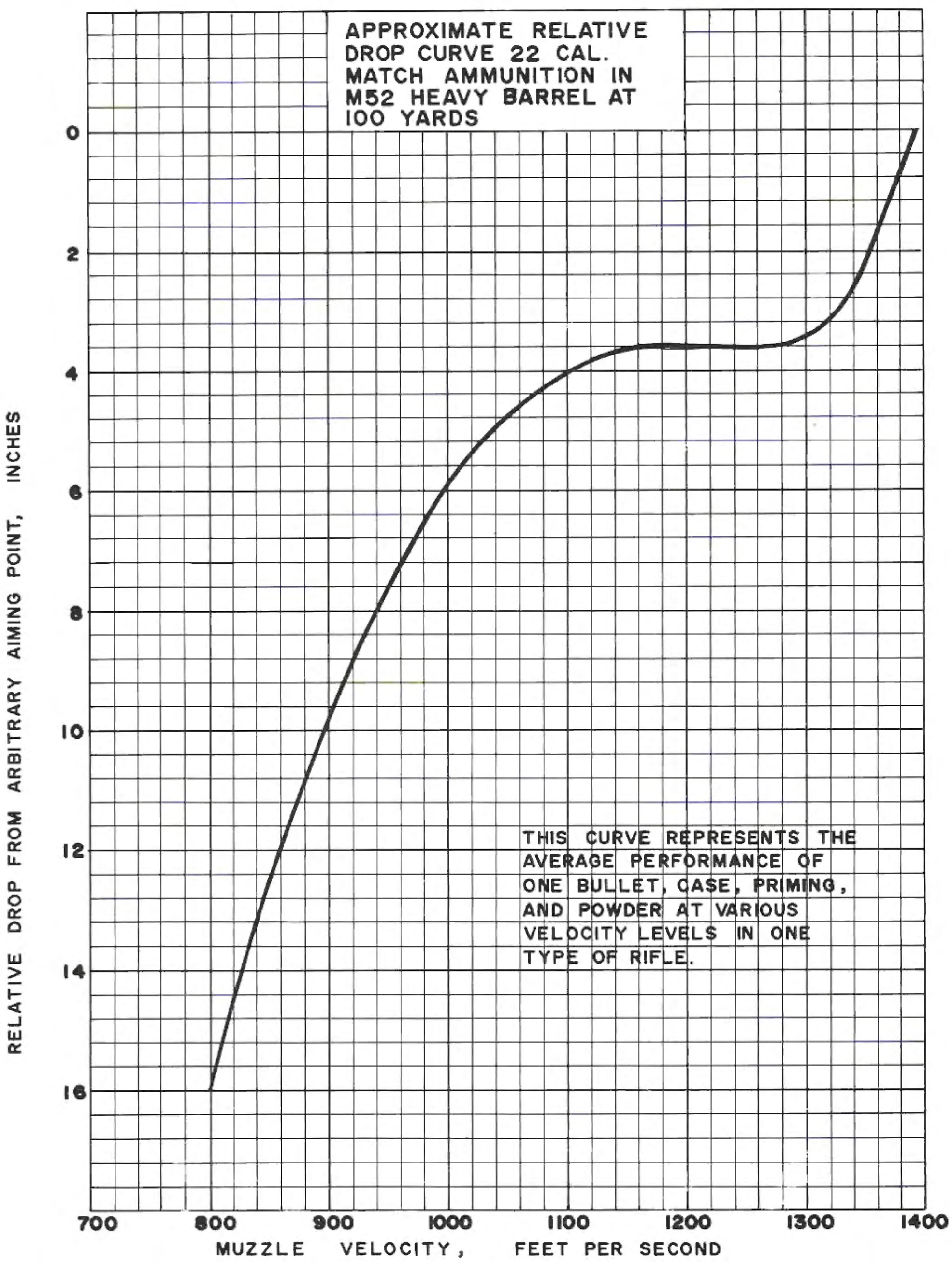


Figure 74

At the moment of exit, expanding gas escapes past the bullet. If the muzzle blast acts equally on the entire circumference of the heel (and boattail), the bullet won't be affected. However, if the heel is not concentric with the body of the bullet, the effect of the muzzle blast won't be evenly applied and the bullet will be nudged off course. This effect, since it occurs only at the muzzle, will be directly proportional to the range.

The break between boattail and the cylindrical section of the bullet body must likewise be a perfect circle.

In passing, it should be noted that the rifle muzzle, if not perfectly square and symmetrical with the bore, will have the same effect on gas flow past the departing bullet.

With jacketed bullets, another effect may occur at the muzzle. Variation in jacket thickness from one side of the bullet to its opposite side creates a situation where the center of gravity does not fall on the geometric axis of the bullet. Lead is heavier than jacket metal. There will be more lead on the side where the jacket is thinner, and the center of gravity will be displaced in that direction.

How serious is this? Take for example a .30 cal. bullet with a side wall .005″ thicker on one side than the other. With the differing density of lead and jacket material, the center of gravity will be moved from the geometric axis about .0008″. With a barrel twist of 10″, each time the bullet moves 10″ forward in the barrel, the centroid moves through a circle $(.0008)(2\pi)$ or .005″ in circumference, and for every foot of travel, it would move $^{12}\!/_{10} \times .005''$ or .006″.

As the bullet leaves the muzzle, the bullet suddenly shifts from rotating around its geometric axis to rotating around its center of gravity, and the lateral movement of .006″ will continue for each forward foot of travel. Dispersion at the target will be directly proportional to the range. At 200-yds. (600 ft.), for instance, it will be .006″ × 600 or 3.6″ from the normal center of impact.

No one can tell, from the loaded round, how to chamber the cartridge so that the imbalance is always in the same location. Hence, the overall effect on accuracy would be to increase the above mentioned 3.6″ to something greater.

Side wall variation in jacket thickness is one of the prime factors in inaccuracy.

Other factors may create the same apparent situation. The barrel itself may modify the bullet in shooting. Bore size and bullet size must be compatible. An oversize bore may allow uneven engraving of rifling on the bullet, heavier on one side than the other. The formation of the bullet's ogive must be concentric with the body of the bullet. The bullet must be round. If throat, bore, and inside of case neck are not all concentric, the bullet may be deformed in firing.

With in-flight effects, the ballistic coefficient of the bullet plays a part. Variation in shape from bullet to bullet changes the coefficient, and thus changes time of flight. Also, surface finish of the bullet, damage in firing which changes the shape of the heel, damage in magazine, all change the apparent ballistic coefficient to some degree.

Changing time of flight not only changes drop, but in turn changes "lag" time, the actual time it takes a bullet to travel a given distance in air versus the time it would take if the bullet traveled the same distance in a vacuum.

Lag time enters into another important area in the accuracy problem—wind drift.

Today's accurate methods of measuring velocities and times of flight over given ranges makes computation of lag time quite accurate also. With lag time accurately determined, calculation of drift for a given wind velocity and direction becomes easy. Drift is directly proportional to lag time.

If the wind is directly across the line of fire, multiplying lag time in seconds by wind velocity in inches per second gives the amount the bullet will have drifted from the initial line of trajectory by the time it reaches the target.

If the wind is not directly across the line of fire, then velocity is multiplied by the cosine of the angle the actual direction makes with the line of fire.

Wind blowing directly toward or away from the shooter has no effect on drift. At an angle of 45°, the cosine is .71, at 30° it is .87, while at 60° it is .50.

With a bullet shape like that of the Super-Match Mark III bullet, minimum lag time over 100 yds., is .018 seconds, and occurs when muzzle velocity is about 1000 f.p.s. At 1200 f.p.s., lag time rises to about .024 seconds.

In a 10 m.p.h. cross wind, equal to 176 inches per second, drift for a 1000 f.p.s. bullet is 3.24″. At 1200 f.p.s. velocity, drift is 4.22″, about 30% more.

At 1140 f.p.s. just above the velocity of sound at sea level (1130 f.p.s. at 70°F), lag time is .022 sec. and drift is 3.87″ in a 10 mile breeze.

Since the 100-yd. 10-Ring is only two inches across, a third of an inch difference in wind drift in a 10 m.p.h. puff becomes important. The drop in velocity of Super-Match ammunition from the 1200 f.p.s. level of Mark II, to 1140 f.p.s. in the Mark III was necessary step. There is still a catch here, however; 1140 f.p.s. is so near the velocity of sound that the change in turbulence with an individual velocity may have an effect. Also, a bullet fired at a velocity above that of sound makes a louder crack than one below sound velocity. The shooter may think that there are big differences in velocities, whereas the actual differences may be rather small.

Another factor is yaw. Like a spinning top, the

bullet wobbles as it leaves the muzzle, but then settles down to steady rotation. Yaw may even begin in the barrel. A short bearing length may let the bullet start to wobble, and wobble plus bullet rotation add up to initial yaw as the bullet leaves the muzzle.

As it yaws, the bullet presents a larger cross section to the air in its path, with a resulting increase in three principal counter forces to its flight: drag, tending to slow the bullet down, a lifting force, tending to change the direction of the bullet, and an over-turning force, tending to make the bullet turn end for end. With an increase in drag, lag time is increased. The lifting force moves the bullet laterally at right angles to the force. The tendency to overturn is countered by the gyroscopic effect of the spinning bullet.

The basic stability of the bullet in flight, which keeps the above factors in check, is a matter of design, and of rifling twist rate.

Yaw on one occasion had an accuracy effect far beyond any reasonable prediction.

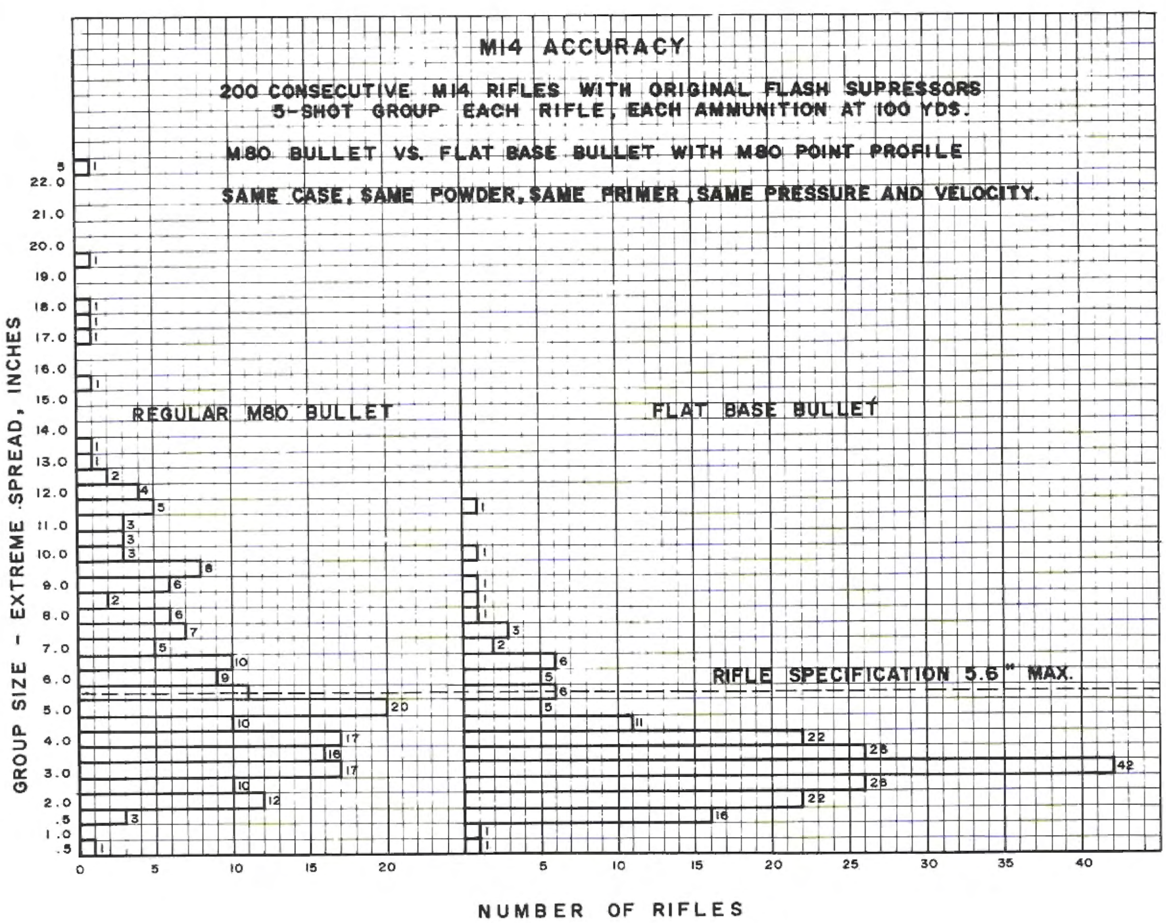
Winchester had just started production of M14 rifles on an Ordnance contract. On acceptance testing for accuracy, these rifles were fired with the standard 7.62 NATO military round, then newly developed. Accuracy on individual rifles was sometimes good, frequently very poor, and only fair on the average. Barrels were of good quality and gauged well within tolerances. No marked difference could be found between good shooting M14's and poor shooting M14's. All other pertinent dimensions were within Ordnance specifications.

On a hunch that the rifle might be sensitive to the 150 gr. M59 NATO bullet with its boattail and consequent short bearing length, some special 150-gr. flat base bullets with the M59 nose profile were loaded in 7.62 NATO cases for trial.

Accuracy barrel results with boattail and flat base bullets were nearly the same, the flat base still being somewhat better.

In rifles, however, there were far different results. Five out of six rifles shot within specification when tested using flat base bullets. More than half of the rifles flunked when the standard boattail bullet was used. Even at that, an occasional M14 did poorly with the flat base bullet, and for no apparent reason. Neither round did really well.

In one test, 170 out of 200 rifles passed the 100-yd. 5.6" accuracy test with the flat based bullet, while, of the same 200 rifles, shot with NATO



M14 ACCURACY

boattail showed only 109 passed. A graphic representation of these results is shown in Table 13.

From the manufacturing standpoint, there had never been much enthusiasm about a 150-gr., .30 cal. boattail bullet, particularly the steel cored NATO bullet, which was hard to make shoot accurately at best. Combining a long ogive, a boattail, and a 150-gr. bullet weight didn't leave much bullet body bearing in the bore of the rifle. There was then some question as to whether the slight possible advantage of better helmet penetration at extreme ranges was worth the extra trouble in bullet production. An informal recommendation was made to consider changing the 7.62 mm M59 bullet back to the familiar .30 cal M2 bullet with its flat base. Before the matter could be even studied, a small shipment of M14's was made to the Marines at Quantico. The rifles were promptly rejected for questionable accuracy, an embarrassment to Army Ordnance. This crisis prompted a full-scale investigation.

Quantico was correct. Some rifles did show poor accuracy, although these rifles had previously passed the prescribed Ordnance tests for accuracy, and the parts had met all specifications for dimension.

Accuracy results were so near the borderline between passing and not passing that some rifles could well pass on one shooting and fail on the next, and vice versa.

The culprit was found to be the flash hider. The Ordnance engineers hadn't planned on the more than normal yaw of the M59 bullet and hadn't provided enough clearance between the inside of the flash hider and the exiting bullet. The boattail bullet yawed so much at exit that it sometimes struck the flash hider and got off to a bad start. The erring dimension was changed, flash hiders enlarged, and the trouble subsided.

Lag time was mentioned earlier—the extra time it takes the bullet to reach the target over the time a bullet could travel the same distance in a vacuum. In other words, without the effect of air resistance.

In so far as a longer time of flight adds to drop, lag time increases drop, and variations in lag time may well add to vertical dispersion.

Control of Accuracy

When one considers the remarkable accuracy bench rest shooters are achieving today versus the variables discussed above, it would seem the bench rest people have done a pretty fair job of sorting out the variables and applying necessary cures.

What Are the Variables?

Velocity Variation:

Velocity control depends on:

Uniform powder charges of the right powder.
Uniform primers working through uniform flash holes.
Uniform bullets as to diameter, jacket hardness, shape and weight.
Uniform fit of bullet to barrel with every bullet.
Careful timing of shots, so that each cartridge is fired at about the same temperature in the chamber.

Barrel Vibration:

Vibration is kept to a minimum and uniform by using:

As stiff a barrel as competition will permit.
Correct bedding. Stiffened receiver.
A velocity level which fits favorably with barrel motion at bullet exit.
Repetitive procedures in shooting: the same hold, the same touch on the trigger, the same rifle position, the same sling tension, uniform handling and loading the cartridge in the chamber, among others.

Barrel:

Smooth inside surfaces, no fouling, no unevenness in dimensions from breech to muzzle, no residual stresses in barrel to change or warp barrel as it heats up. Of course, twist, bore, and groove must match the bullet.

Chamber and Case:

They must match each other dimensionally; case body and neck must be concentric with line of bore; case neck inside must be concentric with neck outside. Throat must be concentric with bore and match the bullet ogive with minimum jump. Flash hole in primer pocket of uniform diameter from case to case.

Bullet:

Normally, bullet diameter should be the same as groove diameter within .0002" or .0003" either way, larger or smaller. As mentioned earlier, the most important feature is wall thickness uniformity. The jacket must be thick enough not to slump under the stress of firing, so that the ogive shape does not change. Change in shape means change in air resistance with a corresponding effect on drop and wind drift. Shape, of course, should be optimum for minimum velocity loss consistent with overall balance and rifle twist.

The main view of accuracy is one of uniformity, consistency in every aspect, in every detail from strip metal for jackets to final forming and sizing. This means much care in making the jacket cup from strip, with cupping dies and punches well centered. The cup punch must be perfectly round, straight, and well polished. Punch must be well centered in the die. Similarly with the draw dies and punches. Checking the jacket side wall with a dial indicator should show variation of .003" or less for ordinary hunting bullets, down to less than .0004" for bench rest accuracy.

Forming the bullet means getting it perfectly

round, with the ogive equally symmetrical. Most of all getting the heel, whether flat or boattailed, to a perfect circle concentric with the body of the bullet.

Dr. Mann, eighty years ago or so, mentioned this strongly in his work on the "Flight of the Bullet from Powder to Target." He found that irregularity in the shape of the nose didn't have nearly as much effect as even the smallest irregularity in the perfection of the heel. Pete Brown used to demonstrate the truth of Dr. Mann's finding in the accuracy tunnel, where no wind blew. He could take ten cartridges from a good-shooting lot of .22 rimfire ammunition, mutilate the bullet noses with a pair of pliers, and shoot a group hardly distinguishable from an unmutilated group. But, taking a good-shooting lot of rimfire match bullets, nicking the heels, then loading and shooting them, spread the shots widely.

The bore itself, if rough in spots, can spoil bullet symmetry either by removing material from the jacket or if the bore is already fouled, the fouling may make the bullet lop-sided in passing over it.

For many years, ammunition makers have known that sizing up rather than down makes a more consistent bullet. This has nothing to do with the motion of the press, but with the relationship between bullet to be sized and diameter of sizing die. By compressing the bullet in a die slightly larger than its diameter, the jacket bulges out together with the lead. After pressure is taken off, the jacket shrinks against the non-elastic lead core, binding the two closely. This is "sizing up," since the bullet diameter is slightly increased.

In the reverse process, passing through a smaller diameter die, the core and jacket are squeezed inward. Afterwards, the jacket expands slightly, the lead does not and the binding is not so intimate. A loose-cored bullet is apt to wander widely. Too large a bullet in too tight a bore and groove move toward the same effect.

Of the three contributors to inaccuracy, the most difficult to control is the shooter. Care and feeding of this animal is beyond the province of this book.

CHAPTER XII THE .22 MATCH CARTRIDGE

Development

Unless someone comes up with a magic formula that makes match quality ammunition as easy to produce as regular cartridges, nobody is apt to make much money out of producing .22 Rimfire Match ammunition.

Producing this very fussy product is either a labor of love, or for prestige. It is not for great profit. The care necessary to make good match, and the ammunition quantities shot up in testing cost far more than the amount that would be spent in making the same amount of regular cartridges.

Then there is the matter of what to make. Not just .22 rimfire, but what velocity, what powder, what pressure, what priming, what bullet shape and alloy, what lubricant, and for what rifles?

For a long time in the U.S., the Winchester Model 52 was the leading rifle choice, used by a majority of the highest ranking shooters. The Remington 37 followed closely. Times changed and the Remington 40-X moved up, and, today, the Model 52 is no longer made. Looking back, my notes show a somewhat prophetic product comparison test of two Model 52's, a Remington 40-X, and Super-Match Mark III and Remington Kleanbore Match. It was easy to see then that the Remington people were making very definite progress in their long battle to have the best combination of gun and ammunition.

This test was in 1958, but the results indicate that the good combinations of gun and ammunition available then would still be among the winners today. The results in detail follow; 10 shot groups were fired at 100 yds.; measurements are extreme spread in inches:

This test, results of which are shown in Table 14, clearly indicated that there were partnerships between guns and ammunition. Mark III worked best in M52's; Remington shot best in the 40-X.

These results are not too surprising. Naturally each company paid more attention to its own rifle-ammunition combination, and had more control over it.

Any match ammunition maker must, as shown above, develop his cartridge in the rifles currently popular among shooters. Somebody comes up with a hot new combination, factory or custom, and wins with it. A few try the same combination and do well. A rush of sorts to join the bandwagon begins. Any match ammunition maker who doesn't keep abreast will likely soon find himself on the outside, looking in. Once out, getting back in is a long, hard battle.

In 1935, Western Super-Match .22 rimfire commanded, to use the word loosely, a very tiny share of the market. It was simply overshadowed by two strong competitors, Remington Palma Match, and Winchester Precision and EZXS.

How good was Super-Match then? A check of 125 consecutive 10-shot targets fired at a range of 100 yds., during the period June 4, to June 11, 1935 averaged 1.5" center to center. Worst target was 3.58", best was .70". The best couldn't get much better. The worst could stand a lot of improvement.

Table 14

	Rifles		
	M52	M52	Rem 40X
Super-Match Mark III	1.04"	1.04"	.90"
	1.16	1.18	.88
	.94	1.10	1.20
	1.66	.74	.92
	.84	.76	.98
	1.05	1.03	.98
Average	1.115"	.975"	.977"
Kleanbore Match	1.92"	1.06"	.88"
	1.52	1.94	.84
	1.24	1.25	.64
	1.20	1.44	.72
	1.34	1.62	1.08
	1.40	1.49	1.05
Average	1.437"	1.477"	.868"

The match cartridge of 1934 was a much different item from the match cartridges of the 1980s. Western's powder of choice was Lesmok, a semi-smokeless blend of gun cotton and blackpowder. Lesmok was easy to ignite. Its bulky grains lent themselves to more accurate powder charging than with smokeless of nearly twice the density. Easy ignition made low bullet pulls possible. Breech pressures were low and the low pressures made the use of gilding metal practical, which in turn led to an easily drawn cartridge case.

All of these things were good, but there was one major drawback. Lesmok left heavy deposits of blackpowder residue in the barrel as fouling. On

a hot, dry day, the fouling caked up. Frequent cleaning, both during and after firing, was necessary. Cleaning wore out barrels faster than the shooting. Also, on damp days, a bouquet of ancient eggs hung heavy over the firing line.

For several years, Western had been working to improve its match ammunition. A small group of Western's technical people were working on several projects relative to accuracy and to the use of smokeless powder in .22 Rimfire Match.

In the technical group was at least one experienced target shooter, Arvel Franz. Later came Bill Woodring and Pete Brown. Bill was already widely known in Eastern shooting circles. The group was interested enough in shooting to spend some time on many Saturdays at the company range.

Informal competition at the range turned into more formal team competition between Sales, Factory and Technical. The Technical group began to bring some of its experimental stuff to the range, while the Factory team brought its pick of the week. Sales, having no other choice, took pot-luck from factory stock.

The weekly match was the Dewar Course, 20 shots at 50 yds., 20 at 100 yds., any sights. In the beginning, any score over 390 looked good. After all, it hadn't been long since the first 400 Dewar had been fired at the National Matches at Camp Perry.

The Technical team members, sometimes working nights on their own time, came up with a product that soon moved scores into the high 390's, with both Factory and Sales, in spite of their good shooters, including Vince Tiefenbrunn and Charley Conrad, trailing after.

Before long, of course, the Factory was pretty much pushed into asking Technical how it was done, and the secret was passed. Scores on all three teams improved to where they were equalling or bettering previous Camp Perry scores on a regular basis.

Western Cartridge Co. rifle shooters of 1939 were so successful that the sales department used their picture for an advertisement. Author "Jack" Frost is seated, on the left, beside Charley Conrad and "Pete" Brown. Vince Tiefenbrunn stands on the left, next to Kay Woodring. Bill Woodring is standing on the right.

Production of the new match cartridge smoothed out and saleable quantities became available. Still no market, no sales to speak of.

Then in 1937, the company fielded a picked team and sent it out to do battle at Camp Ritchie, Sea Girt, some local matches enroute, and finally on to Camp Perry. The team did well as individuals and as a team at each match. Closer to home, the East Alton team cleaned up at the Missouri State matches twice in two years. The third year, a local Missouri rule prevented "any employee of an arms or ammunition company" from shooting as a competitor. The well-attended University of Chicago indoor matches in 1938 and 1939 were dominated by the East Alton team.

By 1940, Super-Match Mark II was averaging less than 1.15". The worst targets were not much worse than 1.6" or 1.7". The best hadn't changed much over the .7 shot in 1935. There were simply more targets down near this point.

At the University of Chicago one year, the extra prize for winning the team match as the chance to compete in a live radio match with a leading British team. Each shooter on each team had a spotter behind him scoring each shot. Results went back and forth via the radio so that a running score could be kept. East Alton won in a walk, being clean, except for two crossfires on his own targets by Bill Woodring. This wouldn't have been so bad except that just prior to the match Bill was heard cautioning Pete Brown not to crossfire. The range layout was very crowded at the fieldhouse at the University, and at one end the firing points were double-decked. Pete earlier had managed to fire an entire 20-shot string on the wrong target, and was credited with 20 crossfires in so doing, probably a range record of sorts.

It became apparent that wherever East Alton showed up the best chance of winning was to join the clan and shoot Super-Match Mark II. It was in this period that Bill Woodring won three consecutive small bore championships at Camp Perry. Sales grew rapidly.

After the war, when shooting resumed, Mark II had a very firm place in the market. When Vince Tiefenbrunn and I made a check of the firing line during one match at the 1947 National Smallbore Championships, well over 90% of the shooters were seen coddling the familiar yellow, blue and red box. In fact, it was rumored that one or two staunch Remington users had sneaked Mark II into Remington boxes. They didn't want their friend, Frank Kahrs, the Remington salesman, to know they'd switched brands.

There was, however, some trouble brewing.

There was talk that Mark II was a fine calm weather cartridge, but was too sensitive to wind. Wind sensitivity hadn't been much of a problem, possibly because conditions had been fairly calm at many of the important matches, and partly because it took some time for people to come to a conclusion on the subject.

By 1949, after the National Championships at Des Moines, Vince Tiefenbrunn had talked to enough shooters to be convinced that the wind sensitivity rumors were true. He convinced the factory that action was necessary.

A test range was set up at East Alton on an open tract of land where the wind had a free sweep. A 100-yd. range was laid out, firing cross wind, with targets and bench rests at each end. By shooting at alternate ends, with rifles zeroed indoors, wind effects were doubled.

With chronographs available to measure times of flight over a 100-yd. range as well as velocities close to the gun muzzle, lag times could be determined quite accurately.

With the combined assistance of the laboratory and the factory in furnishing suitable test ammunition, considerable testing under varying wind conditions was carried out by several of the high ranking shooters who worked for the company. Results bore out the validity of the shooters' feelings about wind sensitivity, as well as the validity of the wind drift formula. The formula, in brief, states that wind drift is directly proportional to lag time in flight and cross wind velocity.

As a result of the tests, three major changes in the match cartridge were found necessary:

(1) The velocity level should be lowered to 1140 f.p.s., just above the velocity of sound. This left the bullet still moving within the velocity range where variations in velocity affect drop the least. (See the graph in Chapter X on Accuracy.)

(2) The shape of the bullet should be changed to reduce drag due to air friction, which is directly responsible for lag. The shoulder on the bullet, created necessarily by the bullet forming punch, was causing most of the reducible drag.

(3) While there had to be lubricant on the body of the bullet to prevent leading, excess lubricant on the nose of the bullet also added to drag.

These three changes showed what had to be done. The problem was how to get them done, and still produce winning accuracy.

Table 15

COMPARISON OF .22 MATCH ACCURACY 1935, 1938, 1954

	125 Consecutive Targets June 4–11, 1935					100 Consecutive Targets Oct. 25–Nov. 2, 1938				100 Consecutive Targets Aug. 8–Sept. 9, 1954			
	2.30	1.85	0.70 –	1.60	1.60	1.15	1.05	1.35	0.90	1.35	0.90	0.90	0.80
	1.57	1.54	1.34	1.50	1.90	0.95	1.30	1.00	1.30	1.45	0.90	1.10	1.20
	1.43	1.15	1.26	2.40	1.50	1.35	1.30	1.60	0.95	1.05	1.40	1.15	0.70
	2.00	1.70	1.95	2.20	1.54	1.35	1.25	1.65	1.55	1.20	1.15	0.75	1.20
	1.83	1.70	2.42	0.92	1.76	1.65 +	1.48	0.95	1.05	0.75	1.30	0.90	0.80
	0.80	1.52	2.90	1.44	0.86	0.80 –	1.25	1.15	1.25	1.30	0.90	1.05	0.90
	1.18	1.34	3.58 +	1.20	1.06	0.80	1.40	1.00	0.85	1.05	0.90	0.90	1.40
	1.32	1.12	1.50	0.76	1.20	0.95	1.75	0.70	0.90	1.25	1.20	1.40	0.90
	1.26	1.45	1.44	1.34	1.40	1.40	1.50	1.35	1.00	1.10	1.20	1.30	0.90
	1.22	1.32	1.32	1.60	1.26	0.95	1.20	0.90	0.95	0.75	1.10	0.90	1.40
	1.06	1.65	0.84	1.86	1.05	1.25	1.40	1.35	1.40	1.45	1.10	0.90	1.30
	1.40	1.23	1.30	1.06	0.87	1.15	1.55	1.05	1.45	1.20	1.15	1.00	0.90
	1.36	1.63	1.52	1.40	1.33	1.20	1.15	1.75	1.30	0.95	1.20	1.20	1.05
	1.16	1.04	1.24	1.40	1.53	1.10	1.95	1.55	1.65	0.85	1.10	0.90	0.90
	1.80	1.97	1.10	1.54	1.83	1.15	1.50	1.35	1.40	0.75	1.15	0.90	1.10
	1.38	1.30	1.60	1.44	1.00	1.25	1.30	1.05	0.90	0.60	1.00	1.05	0.75
	1.62	1.50	2.04	1.74	1.40	1.50	1.10	0.95	1.10	1.10	0.80	0.95	0.80
	2.00	2.10	1.38	1.00	1.15	2.15	1.95	1.15	0.75	0.70	1.20	1.10	0.65
	1.44	1.94	1.12	3.10	0.73	1.10	1.15	1.30	0.90	1.40	0.85	1.00	1.30
	1.24	1.54	1.04	2.04	1.13	1.30	1.25	1.15	1.35	0.90	1.40	0.80	1.35
	1.40	1.75	1.60	1.30	1.32	1.15	1.45	0.70	1.00	0.90	0.95	1.10	0.95
	1.70	1.72	2.30	1.60	0.80	1.15	1.50	1.70	1.30	0.90	1.15	0.80	1.00
	1.68	1.28	1.72	1.70	1.15	1.50	1.30	1.45	1.30	1.25	1.10	0.90	0.95
	1.52	2.00	1.50	1.60	2.12	1.60	1.30	1.05	0.80	1.00	0.95	0.90	0.85
	1.26	1.50	1.28	1.70	1.26	1.00	1.20	0.70	1.00	0.60	0.90	1.25	1.25
Best Target			0.70″					0.70″			0.60″		
Worst Target			3.58					2.15			1.45		
Average			1.50					1.24				1.30	

10 shot groups shot at 100 yds. Model 52 rifle in rest measurements in inches.

Reducing velocity to 1140 ft./sec., while maintaining good velocity *and pressure* uniformity, called for changes in powder, more care at charging, more rigid control over components and priming, and more care at crimping.

Changing the bullet profile called for a new design for the crimper which provided for blending the bullet shoulder into the nose profile.

A new method of lubrication was found which kept the bullet nose essentially clean.

Out of all this study came the Super-Match Mark III. How good was it? A check of 100 targets, 15 fired consecutively each day from August 5 through August 19, 1954, plus 10 more fired when loading was resumed on September 9, 1954, averaged 1.03", center to center. The worst target was 1.45", the best was .60"; 10 of the 100 were .75" or less (See Table 15).

Pistol shooters wanted a round specifically tailored for use in semi-automatic match pistols. In the shorter barrel of the pistol, the powder needed to be a little faster burning than the usual Mark III powder to make sure enough force was developed to operate the slide. Shooters didn't like the greasy Mark III lubricant either. Mark IV was the result. Although it wasn't intended for rifles, quite a few rifle shooters liked it.

It seems now that the shooters' fancy has shifted strongly to Eley ammunition, and RWS. What did Eley do to make a cartridge the shooter finds, or believes, is more accurate?

A year or two ago, I had an opportunity to discuss this matter at length with R. G. Williams of Eley. Bob was Managing Director of the Eley works at the time Tenex was developed. As I rather suspected, the approach that Eley took to match cartridge development was almost exactly the same as Western earlier took to Super-Match. The various factors affecting accuracy were sorted out and worked on, one by one.

There was, however, one difference. Eley sells several target cartridges, of which Tenex is the most accurate. If a lot doesn't make it for Tenex, it can be downgraded to a lesser brand.

With Mark III, there were no lesser brands to fall back on. The velocity of Xpert was higher than Mark III, so that, if the lot failed as Mark III, it couldn't be packed and sold as Xpert. It was scrapped.

Psychologically, this make-or-break approach had a good effect on the crew making the cartridge. With strong emphasis on keeping scrap at a low level, and with no convenient spot to dispose of any sub-standard accuracy, the emphasis was always on making it right. Even so, there were a few days, generally after a plant shut-down, when, despite the best efforts of the production department, the accuracy just wasn't there. When this happened, the watch over the job was doubled. Loading and testing went on at a slow pace until rhythm built up and accuracy climbed back to normal. Tears were shed over the scrap, but so long as all understood that the risk had been deliberate, the final outcome—good accuracy—was justified.

How then is match ammunition made, and how does this differ from making ordinary .22 rimfire cartridges?

Manufacture

The secret, and it needn't be called that, to making match ammunition is uniformity. It is much easier stated than achieved. First, however, comes the setting of various specifications: case dimensions, bullet shape, size, and alloy; powder, velocity and pressure levels, priming type and charge, crimp, knurl and lubricant, together with tool designs to fit. In this regard, there isn't much need to break new ground; copy one of the present successes. Work on subtle changes after good accuracy has been reached with one design.

The Case

Uniformity begins with the selection of brass strip for the case. Thickness variation has to be held to close limits. If not, cup height varies, and bottom thickness will vary, and there will be some effect on later drawing and heading. Likewise, grain size variation should be small, again for uniformity.

From cupping on, the product of each cupping punch is kept as a separate lot. The product of one punch, to begin with, is annealed as a lot to the proper grain size. As experience and, hopefully, success grows cups can be mixed from different punches, provided the product of each punch is like that of every other punch. The larger the lot that can be annealed, the larger the ultimate lot of ammunition can be.

Next, at drawing, the cup punch lot is processed on one draw punch and die, carefully selected as conforming exactly to design. The draw press must be set up to keep variation in side wall thickness to a minimum. Maximum variation should not exceed .0008" for Match; .0005" would be better.

Trimming is done on one machine, adjusted to its most precise operation, and set to mean specification on trimmed length. A control chart is used for length variation control.

As with all match case washing and drying, the lot is processed without mixing with other lots.

At heading, the best header available must be used, adjusted for maximum precision, and set to specification mean. Control charts are to be used on head diameter, thickness, and case overall length. The entire lot is processed on one heading punch set, and without changing the header setup, unless absolutely necessary.

Head diameter gauging, which should be 100%, is set to closer limits than for standard cases. The normal specification is .269–.276″. For match, .2710–.2740″ is a good range, although it might have to be adjusted up or down a little for best sensitivity. Any cases gauged out here can still be used in regular production. Head thickness should be held to .039″–.042″ as a rule.

The headed cases are relief annealed, pickled and washed, again as one lot. Washing must be particularly thorough, so that the priming cavity is perfectly clean.

Priming is critical, both as to charge weight and spinning. The person charging must be experienced, well trained, and especially careful to charge all of each plate exactly the same, with all holes in the plate uniformly full. Only one lot of priming mix is used per lot of cases. Pellet weights must be held well within the normal charge weight range of .27–.31 gr. Any work showing individual charge weights above .40 gr. or below .23 gr. should be either scrapped or shifted to regular production. A control chart is necessary here.

During spinning, cases are frequently checked for smearing of priming on sidewalls. Smearing is to be kept to a minimum. A heavy smear generally indicates either poor alignment of case with spinner bit, or too wet a primer mix. Smeared priming on the sidewall leaves a lesser amount in the rim for ignition. Weaker ignition leads to more velocity variation.

Sensitivity testing is done on a normal basis, except that any work showing an S value above 1.25″, with 4-oz. ball, should call for an immediate check on mix and charging process. At this stage, the lot would not necessarily be rejected for an enlarged S value, since loading and accuracy firing are the next major step, and would provide the final acceptance. If there is any doubt, the lot would be relegated to a lesser category than match.

Primed cases, after drying, are ready for loading except for a final step—mouth spreading. The mouth of the case must be opened up slightly to make it easy to start the bullet into the case without damage. Some priming spinner machines permit an extra punch to bell the mouth, in which case it can be done at spinning. Otherwise it may be done just before powder charging. Either way, the single punch-single machine, working accurately, is the answer. The mouth should be opened up in a perfect circle concentric with the inside of the case, to a diameter .0025″ larger than the case diameter. The included angle of the tapering punch is 45°.

The Bullet

Virgin lead, should be used for the bullet. The problem with reclaimed lead is that the reclamation process is sometimes apt to be a bit haphazard, depending on the operator.

The lead is alloyed with antimony, arsenic, and, if one can afford it, a bit of tin. One usable alloy is 1.5% antimony, .02% arsenic, and the balance lead. An even better alloy, but more expensive because of the high cost of tin, is .15 to .20% antimony, .02% arsenic, and 4 to 5% tin; the rest is lead.

One lot of lead for one lot of bullets is indicated.

Extrusion into wire is probably better done cold, so that the wire is of maximum density and uniformity. After every change of lead billet in the extrusion press, the first wire out is discarded to eliminate any chance of a seam in the wire which could lead to split bullets.

Initial bullet shape before loading depends on tooling, so the tools must be carefully selected for conformity to design. Bullet tooling may not last as long as case tooling, so all punches must be matched.

One lot of bullets is made from one punch, and this lot is kept separate through loading and packing. Work coming from the punch has to be continually checked for signs of punch wear. Weight control should be within a range of ± .05 gr. on any sample of 10 bullets.

The bullet heel is of particular importance in bullet quality. No bullet will shoot well with an imperfect heel. Corners must be sharp, free of flash, free of nicks, and perfectly circular.

Bullets coming off the press must be caught gently, so as not to damage heels. Degreasing must be done without tumbling. A wire basket, into which the bullets are carefully placed, is dunked up and down in solvent or in detergent followed by rinsing in clear water. Drying is in a warm air blast without tumbling.

Following drying, bullets are carefully placed in small boxes of 500 to 1,000 for transfer to the loading room. Bullet lot numbers are plainly marked on the containers.

Any bullets failing to meet match specifications or performance, but otherwise okay, may be shifted to regular production.

Loading

Because of the care needed in handling components, bullets especially, simple plate loading is to be preferred.

The loading process essentially follows the steps outlined in Chapter VII on loading, except that more care is taken, and bullets are not shaken into the bullet plate. Bullets are placed by hand, one at a time into the bullet plate. Care must be taken to protect the heels from nicks.

Powder selection is rather narrow. Eley uses a special powder in Tenex, which is not supposed to be available to other users, being its own special joint development with IMI. Olin Ball powder is, or was, used in Mark III, and should be considered.

Hercules 950 and possibly 1050 have been longtime favorites. The powder must match priming and components with minimum velocity variation, minimum pressure variation, and uniform ignition at the velocity level selected, and permit a relatively low bullet pull.

There are probably European powders that might work, and this possibility should be investigated. One consideration in powder selection that has to be considered is the ability of the powder manufacturer to produce duplicate lots of powder. It would be a waste of time to develop a fine combination only to find that the powder couldn't be duplicated in succeeding lots.

The key individual in plate loading is the powder charger. It is certain that, if minimum variation in velocities is to be expected, there must be an absolute minimum variation in powder charge. The powder charger must exactly duplicate his actions over and over, plate after plate. The same amount of powder must be on the plate, to be swept into the charge holes at the same rate, under the same pressure the full length and width of the plate. Temperature and humidity must be controlled and constant in the charging room. Powder charge weights must be checked freqeuently to make certain that the process is in control. A control chart on powder weights is a must.

Only experience and careful guidance, plus a willingness to work precisely, can make a good powder charger. Needless to say, the same charger should be on the job for the entire ammunition lot or, if the charger is changed, the work of the two chargers should not be mixed.

Powder left on the loading plate during any rest period or work stoppage is not to be used in match loading. It can, however, be used for regular production, so it is not wasted.

Bullet seating is the next operation and calls for great precision. In plate loading, it is common to seat bullets a row at a time. The seating punches must be adjusted to seat each bullet to the same exact depth in the case to the nearest .002" or closer.

It is the practice in some operations to seat a plate of bullets and cases 500 or 1,000 at a time on a hydraulic press. This is not recommended for match cartridges because of the difficulty in adjusting 500 or 1,000 punches individually for length and to fit the cartridge nose. Twenty or 25 punches represent enough of a problem.

Crimping is a crucial operation. The machine itself must be in perfect condition. A new crimp knife and lead knife are used for each lot. During the run, the crimper must not be adjusted, unless bullet pull drops below minimum.

Bullet pull minimum is 40 lbs. Average pull should be between 45 and 50 lbs. It won't be possible to maintain a close tolerance here, unless

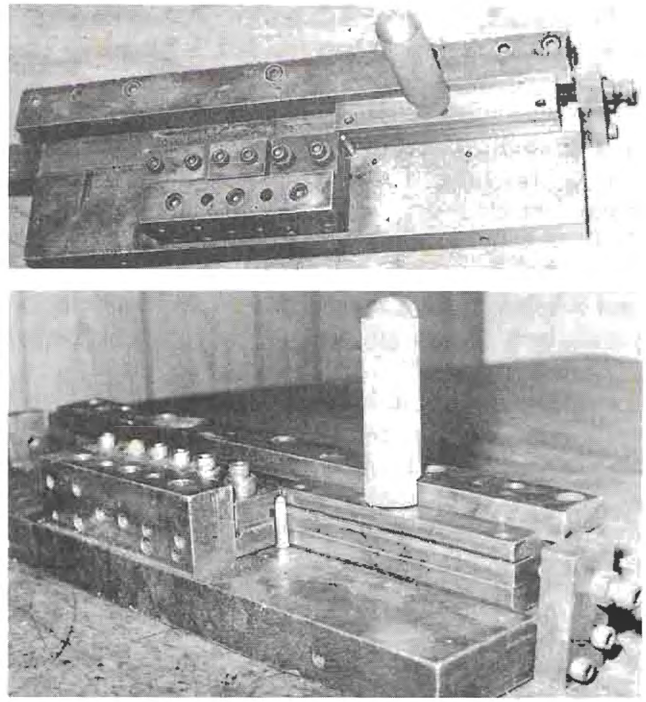


Figure 75: In-line Crimping Tool for Rimfire Cartridges

case length, mouth spreading, bullet heel diameter, and seating depth are held to their individual close tolerances.

The body of the case should not be squeezed any more than necessary to rotate the cartridge as it passes the crimp and lead knives. The drum and knife holder surfaces, where they grip the case, should be lightly sand-blasted to increase the friction on the case without increasing grip pressure. Too much pressure between drum and holder will make the case temporarily oval in shape, reducing the diameter of the bullet heel and leaving the bullet loose under the crimp. Poor accuracy is apt to result.

For experimental work on match, as well as for other .22 rimfire cartridges, it is advantageous to make a small straight-line hand crimper, an example of which is shown in Figure 75. This is easy to set up, does an excellent job of crimping, and is simple to make and to make tooling for.

Bullet diameter and final shape are controlled by the crimper. The crimped cartridge must be left with the bullet rolled perfectly round, and with the crimp even all around the mouth of the case. The lead knife must have left its imprint completely and evenly circular. This means that the rotating drum must not only be perfectly round itself, but must be perfectly concentric with its axis.

Cases are crimped plate by plate in the same order they were charged with powder. After crimping, the sequence, plate by plate, is maintained through lubrication and packing. The general principle here is that maintaining the sequence keeps the variation from cartridge to cartridge at a min-

imum, it being assumed that, while changes will occur, they will be gradual.

For lubrication the cartridges are carefully placed in the lubricating plate by hand. No shaker. The bullet is dipped in the lubricant only deep enough to cover the lead knife line. All excess lubricant must be wiped off the nose of the bullet. An excess of lubricant is to be avoided; only enough to prevent leading should be used. Excess lubricant on the nose affects drag, increasing velocity loss and bullet drop.

The lubricant itself must be kept clean and fresh, and should be changed at least once a day. Discarded lubricant may be used, where called for, in regular production.

Quality Control

1. Strip metal to be selected for uniformity of thickness and grain size.
2. Punches and dies for cupping to be selected for quality cups.
3. Cup tops are to be visibly even and square with sidewalls.
4. Cup lots are to be kept separate through to loading.
5. Grain size after annealing must be well within specification; results are to be recorded.
6. All washing, pickling and drying procedures are to be strictly followed. Washed cups and cases are to be carefully checked for cleanliness and rewashed if necessary.
7. Control charts are to be kept and acted upon wherever called for in manufacturing plan.
8. Sensitivity run-down test to be made on each lot after priming.
9. Bullets from each lot are to be pre-tested with known lots of good cases and powder before approval for loading.
10. Before any lot of cases is accepted for loading, it must be checked with known lots of good bullets and powder. Two or more guns should be used for accuracy testing, and five or more 10-shot groups fired in each rifle. If the cases fail the accuracy test in either rifle, the cases revert to regular production.
11. Ten cartridges are to be checked for bullet pull before start of loading, and every hour thereafter. Before testing for bullet pull, these same ten cartridges are checked for bullet diameter and visible perfection of crimp.
12. After loading starts:
    a. Ten cartridges from the crimper every hour will be checked for powder charge weight.
    b. Velocity and pressure will be checked on 10 rounds at start of loading, and once during shift.
    c. Accuracy will be checked in at least three guns twice each shift, five, 10-shot groups per rifle. Preferably accuracy samples should come from the same production period as samples picked for P and V testing.
    d. After each lot has been loaded and lubricated, final accuracy acceptance will be fired, again with five, 10-shot groups from each of three rifles. For accuracy testing, each set of five groups will be shot with ammunition from one separate plate. As mentioned in the chapter on ballistics, centerfire accuracy is usually shot in heavy Mann barrels in V blocks, while rimfire match is tested in rifles.

For a long time .22 rimfire accuracy was tested in Mann barrels, but it was found that good accuracy from a Mann barrel didn't always mean good accuracy from rifles. The difference was barrel vibration, as discussed in the chapter on accuracy.

One of the reasons Super-Match II and III became successes was a switch to a special rest for testing. In it the rifle was held in as close an approximation as possible to the way a shooter would hold it. Provision was made for a padded forearm rest. Sling tension was provided. The butt was held in position against padding. A 20X telescopic sight was fitted. The entire rig could be minutely adjusted up or down, right or left. Each shot was aimed using a fixed aiming point above the target proper so that the shooter wouldn't be influenced by the group being shot.

The rest provided a controlled environment in which a rifle could be "tuned" to best accuracy by changes in bedding and barrel pressure against the stock.

No hard and fast rules can be set here as to what the accuracy acceptance standards should be. The fact is, simply, that to be competitive, match ammunition must group less than .7" extreme spread for 10-shot groups at 100 yds., in a good match rifle. A .75" average would be considered only fair, but not excellent, and maybe not quite good enough to satisfy a really top notch shooter.

One important thing in this regard is the choice of test rifles. The ammunition must fit the rifles in shooters' hands, or fit the rifles they intend to buy.

As in horse racing, where the horses at work keep changing, and in summer resorts, where the goings-on don't change, but the people doing them come and go, so rifle choices come and go.

The Model 52 rifle is no longer made, the Anschutz has moved up, custom barrels are increasingly popular, the style of bedding and other things have changed. So, as mentioned earlier, the match ammunition maker will have to keep abreast of the changing times, selecting rifles that reflect the current choice of the leaders.

From time to time, therefore, some changes in the cartridge will have to be made, in order to maintain maximum accuracy as the choice of rifles changes.

CHAPTER XIII QUALITY CONTROL

Frequently visitors, particularly of late, ask what they feel is a searching question, "Where is your Quality Control?". The idea seems to be that somewhere there should be a prominent sign "QUALITY CONTROL" and that under it sits a group of stern-faced, gimlet-eyed, diligent people solemnly passing judgment on the product. In the ammunition business it doesn't work that way, and probably wouldn't work elsewhere either in very many places.

Good ammunition was being made long before Quality Control (QC) became a household word. Quality Control, by that name, arrived during World War II. Pioneer work in scientific sampling using statistical methods was a development of Messrs. Shewhart, Dodge and Romig of Bell Telephone. During the war, it was adopted by the supply side of the Army, aided and abetted by General Leslie Simon.

The Poisson distribution and its now familiar bell-shaped curve was something most pre-war engineers scanned briefly upon its mention in mathematics, yawned, and passed up for something more interesting. True, as far back as 1924, some thought was being given to applying statistical methods in the control of quality by Dr. Shewhart, but the idea didn't get past the theoretical stage, outside of Western Electric, until the war.

What the statistical quality control concepts did for ammunition, and for a lot of other businesses as well, was to put decision making on quality problems on a mathematical basis, as opposed to the traditional seat-of-the-pants decisions made by chief inspectors and others with long practical experience. Statistical methods of analysis do short-cut the amount of testing needed to reach a conclusion. This saves money, experimental costs, material, and expensive manpower. Further, the proper design of a test goes far to eliminate any bias that might in earlier times have influenced an inspector.

Commercial Ammunition

Traditionally at Western Cartridge, quality matters were in the bailiwick of a "Chief Inspector," who had inspection sections in each of the various departments, as well as the Ballistics Lab, reporting to him.

The Chief Inspector and the Plant Production Superintendent were on the same managerial level and reported separately to upper management.

For years this arrangement had been going on, based on some simple premises, equally good and valid today:

1. The way to make good ammunition was to develop as defect free a process as economically possible.
2. Production should stick to the process without deviation, unless QC and Engineering agree to any changes.
3. Basic responsibility for quality should be in the hands of the production people, from the operator up.
4. Inspectors should be used to check, test and police the process, and keep production closely advised as to any changes for the worse.
5. No production personnel could ever overrule an inspector on matters of quality.
6. Engineering, Production, and Quality Control should participate in a constant search for ways to improve process and product still further.

During the years when I worked at East Alton, and was frequently touring the plant with visitors, one could see a person or two here and there obviously inspecting something. There was a small area where empty shotshells were being checked over. One girl was operating a test machine which pulled heads off sample shells as one quality check. Another area was down near the packing room, where the loaded product was being given a final once-over. Among the busy machines in the metallic department, a girl was checking samples from machine to machine. Outside one could hear the sound of firing from the random pit. The general inspection activity was far from fevered, but it was obviously effective. Some of the best ammunition in the world was being made.

The Chief Inspector then was a Russian by the name of Victor Crasnoff. By education he was a railway engineer. He didn't run locomotives, he was educated to design railroads and rail equipment.

Victor had come to the States before World War I and was working for the firm of Babcock & Wilcox, boiler makers, before the Russian revolution. The Czarist government, which was purchasing ammunition from Western, needed an inspector on the spot and Victor was designated. Then came the revolution and suddenly Victor had no home to return to. Because he had done very well as an inspector, Western hired him and put

him to work. Over the years, he was promoted to Chief Inspector.

When I was transferred to Ammunition Sales, Victor became my mentor on ammunition making. Each day for some period of time I took a trip for an hour or more through one of the plant's departments. I then went back to my desk and wrote up what I had seen and been told. Later, I took the write-up back to Victor to verify its accuracy. We had far more arguments over my use of English and grammar than we did over the content of the write-ups. Educated in Russian, with English only a second language, his command of grammar was better than mine. He usually capped an argument by hauling down a much thumbed grammar and pointing out the authority for his side of the argument. Generally he won. His grammar was better than his accent, still heavily Russian, but he was seldom misunderstood. Many things in these pages came from the "little black book" he helped me start. Between us, Quality Control was never mentioned, but there was no question about his uncompromising attitude toward quality.

Quality Control is not an entity like a big wrench that can reach out and tighten a nut when it becomes loose. It is more a state of mind and attitude that starts with management and extends down to every individual in the organization. Make it right if possible, but don't bury it or mix it in if it's not right. A few bad rounds can spoil the value of a million rounds of ammunition, as well as a company's reputation.

A proper attitude toward quality has to start with the highest level of management. The desire for quality must be constantly and forcefully demonstrated by management. If top management allows a compromise on necessary quality in order to get production out, the operator and the inspector in the shop know it and relax. An increase in poor work results, and further compromise is requested. If substandard quality is continually allowed to pass, the decline tends to snowball. Maybe I was fortunate, but never in my years in Quality Control and in Production did higher management anywhere suggest, let alone order, a compromise on quality. Not that a Quality Control Manager doesn't get shot at by his production peers sometimes for being hard-hearted. That's part of the game.

In 1950, I moved from East Alton to New Haven to organize a Product Service Division, and became the first Product Service Manager. After two years, the corporation reorganized and I became the first Winchester-Western Division Quality Control Manager, with responsibility for the New Haven Arms and Ammunition plant and the East Alton Ammunition Plant.

Chief Inspectors were no longer the "in" thing, but they had left a permanent legacy in their methods to control quality as well as a highly competent staff in both plants. Some reassignment of personnel, a change to new QC type titles, and the business of making quality ammunition went on pretty much as before. We did add one new department, QC Engineering, whose role was that of finding ways to cut inspection costs by reducing unnecessary inspection, making process capability studies, designing experiments for maximum information with minimum testing, and analysis of all statistical data. I dashed off to New Haven College for a night course in Statistical Quality Control (SQC), then a very new course. The value of SQC became immediately apparent.

So much for history and philosophy. How does QC in ammunition work? The full answer is far from short. On one occasion, the president of Olin, asked this question. The answer we gave him, condensed, but well documented with charts, tables, and graphs, ran about 200 pages. The answer here will be a little more brief.

In a nutshell, the six premises stated earlier are the basis for the QC function.

First, the process. It will be fully described in process sheets that specify raw material as to all pertinent physical characteristics, tools, gauges, physical checks, control limits for charts, part dimensions, machines to be used, and all tests to be made.

Ammunition components have very definite tolerance limits as to dimension. The machines which perform the operations must be capable of working within these tolerances, and kept that way. Wherever a tolerance is critical as regards the ability of the process to meet it, control charts are kept, *at the machine*. This is a QC job, first to set up the control chart, then to keep the chart, and to inform the operator if the process is approaching limits of control.

QC is also responsible for making sure the gauges on the job are properly calibrated. A gauge inspection schedule, strictly adhered to, is called for.

All tools, dies, and punches are inspected by QC before issue. No alteration of tools in the production area is permitted unless approved by QC and Engineering.

There was a time in one plant that there were bench polishing machines in the production area. Each machine adjustor felt he knew better how to make the tool or die than the engineer and the tool room and applied his own final polish. No two tools ended up alike, making a uniform product next to impossible, and the variety in the output proved it. Scrap was high. The polishing heads came out of the shop. It was not a happy move, for a while; feelings were hurt. The adjustors weren't all wrong. Some permanent tool alterations had to be made. But, scrap decreased markedly and quality improved.

Incoming material, ordered to specification, is checked by QC before issue. Generally, the testing laboratory is under QC supervision, but lab services are available to all who need them.

Metallurgy checks during processing are made as needed by QC Again, such checks are specified in the process sheets.

In-process inspections on the machine should be made by the operator, so long as operator time permits. All work coming off the machine goes into a catch basket and stays at the machine until checked by the roving QC Inspector. Following the Inspector's okay, the work may be dumped into larger transfer containers to go to the next operation.

Whenever a tool is changed, first piece inspection by QC, as well as the set-up man, assures that the machine is ready to start. The machine is not permitted to start until this check has been made. Any set-up scrap is immediately placed in a scrap container, so that it runs no danger of being mixed with good work.

All scrap generated is identified as to date and machine. QC reviews the scrap on a daily basis, assigns cause, and makes a report, showing quantity, operation responsible, and disposition. If scrap for the period exceeds assigned limits, production heads responsible are immediately notified. When only very small quantities of scrap are produced, weekly accumulations may be permitted.

Feedback of inspection results so as to correct operations is an important QC function. Reports must be as immediate as possible before additional large quantities of defective material are produced.

All these things are routine, or should be, in any repetitive process in metal working. Ammunition making simply requires that the processes be capable of producing material entirely within dimensional limits, and that the material is kept within those limits by constant checking.

In certain destructive tests, such as bullet pulls, primer drop testing for sensitivity, pressures, velocities, and accuracy, among others, only enough rounds are used up to give a fair estimate of the current corresponding level in the product. Ten bullet pulls for instance, if within normal range, are enough. Routine sensitivities are checked by firing 25 or 50 shells at a fixed height, rather than shooting a full run-down test. Ten pressures and velocities are usually enough at a time. Accuracy is usually five groups of 10 shots each. The frequency with which the tests are performed is adjusted to minimize the risk of producing a defective product between tests. Even with shooting held to a minimum, the number of rounds fired yearly can run into large figures. In the combined W-W operation, including the arms plant, about 10 million rounds a year never made it through the gate, being shot up in testing. Armscor, in Manila, burns up nearly a million rounds each month.

In the random shooting of ammunition, the purpose is not for direct acceptance or rejection of ammunition lots. Sampling tables do not provide for sample sizes to check for Acceptable Quality Levels (AQL's) of .002% for instance, which is what the factory considers a reasonable figure for permissible misfires in production. One misfire allowed in 50,000 rounds, .002%, would require the shooting of about 100,000 rounds for reasonable assurance. No misfire might occur in the first 50,000 rounds tested, yet three or four could appear in the next 50,000. Or two could show up in the first 50,000, and none in the next 50,000. Either way, it is obvious that sampling lot to lot won't work here. There would be little left to ship.

What the factory does, therefore, is to keep accurate records on a cumulative basis, in order to judge the average outgoing quality. Any trend showing an increase in any malfunction versus rounds fired is cause for investigation. Every individual malfunction is carefully analyzed as to cause. Judgment is then made as to action necessary, if any. A single burst head, for instance, may call for an immediate shut-down of the loading operation for corrective action, and a hold up of the ammunition already loaded for function check.

Military Ammunition

Military ammunition production has its quality controlled during manufacture in the same manner as does commercial ammunition. However, acceptance by the military is under an entirely different procedure than for the commercial product. Formal sampling, examination of the sample, and acceptance or rejection of the ammunition by lots is the military method.

Going by the demonstrated quality levels maintained in the factory on both commercial and military ammunition, it would seem that the government could save a good bit of money by simply accepting the manufacturer's guarantee of quality. The acceptance procedure is costly and the government pays the cost in the final price of the product.

U.S. Military Specifications for ammunition acceptance call for the use of sampling plans outlined in tables in a publication "MIL Std-105D." The sample size is dictated by the lot size being submitted, as well as the general inspection level. Inspection may be on a normal, tightened, or reduced level, depending on the quality level of preceding lots submitted. The plan then shows, for each A.Q.L., a pair of numbers. If the number of defects found in the sample is less than the small number, the lot is accepted. If more defects are found than the smaller number, the lot is rejected.

A more complicated plan calls for a permissible double sampling. If the first sample fails, an additional sample, double the size of the first, may be drawn. The defects from the first and second samples are totalled, and the lot finally accepted or rejected according to the numbers shown on the second sample line underneath the appropriate A.Q.L. Table 16 shows the inspection plan for double sampling at an A.Q.L. of .25%. Level II refers to a normal inspection level for severity.

If a lot is rejected, it must be reinspected for the defects described before resubmission.

Defects are classified as critical, major, or minor. A critical defect is one which could cause serious injury or worse to personnel.

A major defect is one which could be critical or nearly so, but for which a subsequent check completely eliminates the danger. Also, a defect which could cause a failure to function.

A minor defect is one which could be major, but for which a subsequent check completely eliminates the defect. Also, one which causes a general loss of effectiveness, but does not cause a specific malfunction.

A current contract for 5.56 mm military ammunition manufacture lists visual and gauging defects as follows:

Critical	Major	Minor
0% allowed	**A.Q.L. .25% defects allowed**	**A.Q.L. 1.5% defects allowed**
Split case	**Stained, etched case**	**Stained**
Perforated case	**Round head**	**Scratch**
No primer	**Mouth not crimped in cannalure**	**Wrinkle or fold**
Cocked primer	**No mouth anneal**	**No head stamp**

Essentially, the specifications are established to insure proper functioning and performance with safety in standard military rifles chambered for the particular cartridges involved.

Function testing is checked by firing a sample of specified size in one or more specified weapons. Again, a retest is permitted if more than a permissible minimum number of defects but less than a maximum number occur. Defects for both test and retest are totalled. A retest calls for double the number of rounds in the first sample.

In any ammunition plant, properly run, the number of lots rejected will be very, very few. My notes from one plant show, for instance, that over one 2-year period, when millions of rounds of 7.62 mm NATO and .30-'.06 ammunition were being loaded, the number of defects found in firing about a hundred thousand rounds was zero, and the number of inspection and gauging defects, 90% of which were minor, was only .088%. No lots were rejected, or reinspected. Obviously, the quality level was far better than that which would have been permissible for acceptance.

On one occasion at New Haven, the Resident Inspector of Ordnance (RIO) came in with a report that in function testing one lot of 7.62 mm ammunition for acceptance, one misfire occurred. Examination showed the cartridge was without powder; a critical defect, cause to reject the entire lot, which he proposed to do.

In view of what had gone on during the company's final 100% inspection, and what the Ordnance people were supposed to have done in inspecting the sample, the round with a missing powder charge had to have led a charmed life to have reached the firing stage.

Table 16

MIL-STD-105A Double Sampling Table

AQL of .25% for Normal Inspection on Level II

Lot Size	Sample	Sample Size	Acceptance Number	Rejection Number
1 to 50	——	100% Inspection Required ——		
51 to 800	Single	50	0	1
801 to 3200	First	100	0	3
	Second	200	2	3
3201 to 8000	First	150	1	3
	Second	300	2	3
8001 to 22,000	First	200	1	6
	Second	400	5	6
22,001 to 110,000	First	300	2	7
	Second	600	6	7
110,001 to 550,000	First	500	3	10
	Second	1000	9	10
550,001 and over	First	1000	5	17
	Second	2000	16	17

ALSO USE THIS TABLE FOR: AQL of .40% for Tightened Inspection on Level II

The company had passed all the lot over an automatic gauging and weighing machine. Any cartridge without powder should have been rejected, if the machine was working properly. A cartridge without powder would have fallen into a locked box, only opened by a supervisor and an Ordnance representative. Even one missing powder charge would have been the cause of an immediate uproar. In addition, if the loading machine had failed on its powder loading and detection station, there should have been more than one such round. None had been reported.

Next, the Ordnance people ran the sample over their own separate weighing machine. Again, the cartridge would have been thrown out if the machine was working properly.

The weighing machine has 18 balance arms which revolve in a circle, each weighted so that a light cartridge leaves the arm raised. A fixed arm pushes the light cartridge off into a locked box as the balance arm revolves past the fixed arm.

The sample from a one-million round lot was 1250 cartridges. Assuming there was only 1 round without powder in the lot, since no others were found, the chances were 1,250 : 1,000,000 or 1 in 800 that the round would be in the sample.

Further, there are 18 arms on the weighing machine. If one arm was not working, the odds that the no powder load would fall on it would be 18 : 1,250 or 1 in 69. The combined odds would then be 1 in 55,200.

Beyond this, the odds that the cartridge would fall on a defective weigh arm on the Ordnance machine as well were again 1 in 69. The combined odds that all three events would happen to the single cartridge are something like 1 in 3,808,800.

This lack of likelihood was pointed out to the RIO and it was suggested that he look for a better explanation. He was also informed that the company would protest the rejection; not only because of the cost of reinspection, but because the rejection would spoil the company's record. Bud Jones, who was then serving as RIO, went away and came back in about an hour with the answer. One of his people had pushed a bullet back into an empty case at the bullet pull machine, and the round had gotten mixed in the sample. There were 480 fired cases and the one misfire on their inspection table, one more than the sample. Both weighing machines were found in perfect operating condition.

Over the years, there were few arguments or differences with the Ordnance people. The most frequent minor disagreement was in velocity measurements. The counter chronographs then in use were not the compact, reliable, transistor/printed circuit types in use today. The earlier instruments were stuffed with a multitude of 12AU7 vacuum tubes, not a particularly stable type. One tube, going a little haywire, could put the velocity results in doubt without drawing attention to itself. Only when different test barrels gave different results would suspicion finally fall on the chronograph. Then, all tubes would be checked, and the offender replaced. After that velocities usually fell into line again. Even so, these early chronographs were a lot more convenient than the older Boulengé type.

There was even worse trouble with the first chronograph used in Manilla. It never did give proper readings, being consistently about 30% low. For a time, we had to resort to shooting U.S.-made ammunition along with our production, merely keeping the results comparable by getting the same reading. It was assumed that the U.S. velocities were reasonably in line with SAAMI recommendations. Several local electronics experts failed to find the trouble, and the machine was retired, without honor.

In the chapter on Ballistics in the Factory, the conduct of the various tests for control of product performance is covered. These are all very much a part of quality control. They must be conducted as nearly concurrent with production as possible. There must be immediate feedback to production on any irregularities which show up. Nothing is more conducive to a desire to relax standards than a pile of doubtful material, always "temporarily relax, of course," says Production. The larger the pile the more possibly usable it seems, and the longer it waits before disposal the more the pile is apt to grow. People seem to get increasingly sentimental about it.

It seems elemental, but over the years it becomes more and more abundantly clear that an attitude of "so what" toward quality is mainly a management failure to make clear to the individual employee exactly what constitutes quality, as far as he or she is concerned. A good beginning is a very clear, very concise, and complete specification for the process and the resultant product. Emphasis on the process.

CHAPTER XIV
FIRES AND EXPLOSIONS

Although ammunition plant explosions are rare, when one occurs it usually makes headlines. A fatality in an auto wreck rates far less attention, yet an individual is probably safer in an ammunition plant than on the road.

Because the explosive industry has long been strongly safety conscious, the accidental explosion frequency is much less than the serious accident frequency in more common businesses. As in airplane crashes, however, one either survives an explosion, mostly undamaged, or one becomes a statistic.

Anyone who has worked in this kind of an industry very long will have knowledge, sometimes direct or from some survivor, but usually as part of industry lore, of one or more fires and explosions. Generally, when an explosion occurs, information on the cause quietly is passed around the industry so that all may profit from experience. There is no attempt to cover up causes; they are simply stated so that all may learn.

When working around explosives one cultivates, or should cultivate if one wants to survive, a habit of obeying the safety regulations, knowing that such regulations have, over the years, been distilled down to essentially pure substance.

My first experience in a "blow" came fairly soon after I started to work. My small laboratory was in an area in the plant where railway torpedoes and railway fusees were made. It was a bright sunshiny spring day. It seems, for reasons unknown, that most blows occur on exceptionally nice days.

I had mounted a small centrifuge on the sill of an open window and was spinning nitroglycerine out of a small sample of dynamite filler. Suddenly, without any warning, there was a very loud boom and a rush of air. My centrifuge, being uninvolved, continued to whirl merrily. It being my first experience, I stood for a moment undecided as to what to do. Turning around, I saw that Andy Anderson, the over-all man in charge of the operation, was calmly standing in a doorway. He said it was a good idea to stand in the doorway, so we would know which way to jump if the building fell, which fortunately, it didn't. Outside was a pall of smoke. The explosion had occured less than 50 yds. away. Underneath the spreading smoke cloud, we could see the legs of running women coming out of a nearby building. One or two had fainted, but they did not seem to be damaged. Several shouted that "George was there." The "George" did not refer to me; it referred to the superintendent of that section. George was nowhere in sight, and a small building, a dryer, had likewise disappeared, leaving a bare concrete floor. On a small embankment back of the floor was a radiator from the dryer. Ernie Silk and I lifted the radiator and found a leg. A further search, by others, located most of the rest of George, about 30 yds. away underneath an abandoned mixer.

George, as was his custom, had gone into the dryer to check the drying railway torpedo tablets. While he was making his check, the whole dryer charge, about 200 lbs. of torpedo tablets, had exploded. No one ever knew why. Torpedoes are made from a chlorate-sulfur mixture, though, which is quite explosive.

Needless to say, it was a salutory lesson. With this experience so early in my career, I have possibly been more than normally concerned about safety ever since.

As a rule of thumb, it might be considered that initiating explosives such as lead styphnate detonate, while black and smokeless powder burn, rapidly as they are intended to, but without detonation.

That blackpowder burns, but will not detonate, is true.

Editor's Note: Blackpowder burns with sufficient violence that, when properly tamped or confined, its effect is "explosive" even if the way it burns is not. Hence its use in explosive munitions and for blasting.

That is not necessarily true with smokeless powder, especially with small grain, high nitroglycerine types. Extensive work by Olin, Canadian Industries, and others indicates that smokeless powder is sometimes much easier to detonate than previously believed. A blast at Norma in Sweden several years ago is a case in point.

The powder distribution system in most loading rooms calls for a reservoir holding a quantity of powder to be located in a protected area some distance from the loading machine. Powder from the reservoir is gravity-fed, through a pipe, to a small hopper on the loading machine.

If this delivery pipe is too small in diameter, a fire starting on the loading machine may cause the powder in the pipe to detonate if the height of powder in the pipe is more than a few inches. This is apparently what happened at Norma.

Smokeless powder in ammunition burns at a rate normally dependent on pressure. When confined, as in the distribution tube in larger amounts

than in a cartridge, the temperature rises to critical heights. With the temperature rise comes a rise in burning rate to a critical point where detonation instead of burning occurs.

Prevention of this type of accident consists of:

1. Making the distribution pipe more than 1" in diameter inside.
2. Providing a thin "blow out" section, or sections, along the pipe, so that inside pressure cannot build up in case of fire.
3. Making sure that the powder hopper at the loading machine has no lengthy small diameter constriction, and that the depth of powder is kept at a low level.
4. Keeping the delivery tube empty as much of the time as possible, with a cut-off near the main reservoir.

These steps take care of the detonation possibility. Fire on the loading machine is still a serious matter. Even a few pounds of powder in the hopper can make a fierce blaze. Venting the flame outside by means of a pipe the diameter of the top of the hopper, and fitting tightly on the hopper, protects the operator, as well as the loading room.

Initiating explosives, such as lead styphnate, of course, can be expected to detonate whenever they are dry and properly irritated. They do not burn. Wet priming mix may or may not burn or detonate, depending on moisture content.

Blackpowder, on the other hand, burns at an extremely rapid rate. It is especially sensitive to static electricity or spark and is the most hazardous of explosive materials in ordinary handling.

In ammunition manufacturing operations, the most likely areas for explosions and fires are in the magazines, and on loading machines and mixers.

Every possible precaution is taken around magazines to make sure that fires do not start, because in this case fires may lead to detonations. Good magazines are barricaded or revetted with earth to a height at least equal to that of the roof. The barricades are built far enough from the magazines whereby if the magazine does explode the barricade will not be blown over but will contain the explosion so that most of the force will be essentially upward. The magazine is constructed generally of light material, so that, if it does explode, heavy pieces will not be blown about. Those pieces which are blown sideways will be stopped by the barricade. The magazines themselves should be made with good ventilation, good ceiling insulation, so that they do not overheat, and with non-sparking floors. Areas surrounding the magazine must be kept clear of combustible material, such as dry grass.

The contents need further protection. An old-fashioned anarchist, now called a dissident, firing a shot through a thin walled magazine might be pleased with the result, but few others will rejoice. A rifle bullet, not necessarily a tracer, hitting a large-capacity, bulk-storage container of powder may set if off.

Double-wall construction is a good solution. Outer and inner walls may be of either light metal or asbestos-concrete sheet. The six-inch space between them is filled with 1/2" to 3/4" gravel. Most bullets striking the stones will break up before penetrating all the way.

Sand is not suitable. A military rifle bullet can penetrate two or more feet of wet sand. It is difficult to keep sand dry in magazine walls. Gravel, being light, quickly loses velocity and if an explosion occurs, is not nearly as dangerous as flying chunks of solid concrete.

In the factory the rule is that wherever there is an explosive hazard, the amount of explosive present is held below a specified limit. There are some places where certain exposure to explosives is necessary. All such hazardous areas are barricaded. The barricades themselves must be strong enough and far enough from an accidental explosion that they cannot be blown out and cause damage. The number of people permitted to be present at any one time is also severely limited.

At Cascade Cartridge, sometime before I arrived, an explosion had occurred on a loading machine, one of the kind where 1,000 primers were handled at one time. An operator, standing near the machine, was struck by the shield and killed. The shield was too confining. Had the shield been another foot or two away from the machine, the accident might not have been serious.

A more recent explosion in Bangkok, Thailand, points out very vividly the dangers of keeping too much loaded material and explosive-in-process in the same area.

In Bangkok, completed rockets were being stored in the same room in which other rockets were being loaded. An explosion occurred that leveled an area of about six acres-worth of surrounding buildings and squatter homes and a great many people were killed. It was complete folly and gross carelessness to have kept this much explosive material in one area, particularly when the surrounding area was crowded with people. Many innocents died.

With smokeless powder, around a loading machine, provided the constrictions mentioned above are eliminated, the major hazard is one of a flash fire. Smokeless powder burns exceedingly rapidly and the radiant heat from even a few pounds is enough to burn people some distance away from the fire. To protect people nearby, then, the machine should be barricaded with a flash protecting barricade. It is important to provide a solid flameproof duct leading from the reservoir on the powder machine to the outside, so that, if the powder burns, the flash does not spread through the loading room.

One of the things that must be specially protected against, particularly in areas where humidity during the winter months is very low, is static electricity. Floors where powder is being handled should be conductive. All machines should be thoroughly grounded, and personnel should be grounded as well. This may sound difficult, but it can be done by having the occasional visitor entering the room carry in his hand a metal rod, which he can drag on the conductive floor. This keeps him permanently grounded. Working personnel may use other more convenient means.

Going barefoot would be another solution, but is not recommended.

Here in the Philippines the humidity is generally high enough that static is not a problem. Humidity control in climates where outside temperatures are low, is to be seriously considered.

Just before writing this chapter, a clipping came in from Canada reporting an explosion at Expro Chemical Company's powder plant in Valleyfield, Que. The cause was listed as static. Of the four people in the building, two died and the two others were hospitalized with burns. The fire occurred in a building where some 4,000 lbs. of powder was present. The building was a dryer. Although the people were wearing non-static clothing, which is another good idea, somewhere a spark was struck, probably from static, and in the very dry atmosphere of the dryer the fire occurred.

The Valleyfield plant is now producing the IMR series of powders formerly made by DuPont. The DuPont powder plant itself burned several years ago, and has not been rebuilt.

Formerly, most of the lighting in explosive areas was with incandescent bulbs surrounded by a heavy glass globe in turn protected by a metallic grill. With today's more popular use of fluorescent lighting, a different system may be used, eliminating the light robbing globe and grill. The most vulnerable part of the fluorescent system is the ballast, which is known to burn out quite often and does present a fire hazard from dripping insulating tar.

Any time that fluorescent lighting is used, therefore in an explosive area, the ballast should be installed outside the room and wired in to the fluorescent tube. It is still a good measure to protect the tube with a screen, so that it does not get bumped. It goes without saying that all light switches and all electric motors should be spark-proof and totally enclosed.

In the areas where explosive materials, such as trinitroresorcinol, lead styphnate, and tetracene, are handled, the first and foremost precaution is that of maintaining absolute cleanliness, so that explosive material does not gather in corners, in cracks in the floor, and similar places. Second, the building must be kept high in humidity, even damp, so that there is no chance for priming to dry out. Third, the amount of explosive present, as well as the number of people present, must be restricted to the minimum practical. People must wear safety glasses.

To protect against lead poisoning and poisoning by absorption of the various nitrated chemicals, rubber gloves should be worn whenever these explosive compounds are handled. Damp priming mix generally will not detonate, but it can burn. People handling mix should have immediate access to an overhead shower, under which it is only necessary to step to start the shower.

Beyond the actual explosive handling areas, the most likely spot for explosion to occur is in the priming area sumps leading to the sewers. Most of the accidents that have occurred in recent years, in priming operations, seem to have centered around the cleaning of these sumps. Appropriate measures must be taken here to prevent explosion. Such explosions are not particularly violent, but they may be heavy enough and strong enough to do a lot of damage to a person working directly over the sump. Styphnate and tetracene residues must be chemically destroyed at regularly scheduled intervals.

All explosive areas, particularly where dry chemicals, such as powder, are being handled, must be provided with pressured sprinkling systems. Special rapid acting sprinkler heads are available and must be used. Even burning smokeless powder, if caught soon enough by a pressured sprinkler, may be extinguished. Sprinklers should be mounted a foot or less above powder drying trays, for instance.

In 1978, Squires Bingham had its first, and I hope its only, fire. Some 3 million rounds of .22 LR and 5.56 mm military were in the middle of the blaze. It happened on a Sunday.

The company, at the time, was expanding and rearranging the ammunition plant. New loading rooms, as fire-proof as they could be made, were just finished, and due to be occupied the following week. Two temporary loading rooms had been set up on the opposite side of the building from the original room. Ceilings were of plywood to enclose the area for air conditioning. The ammunition was temporarily on the floor between the loading rooms, ready for shipment Monday. Only a small maintenance crew, plus the tool room shift were working. This sets the stage.

It had been a long standing company rule that any welder working in the plant had to be accompanied by an assistant, equipped with a fire extinguisher. A welder from the maintenance crew, knowing that a fire couldn't possibly happen on a Sunday, chose to work alone, and above the temporary loading rooms. A spark fell between his feet and lit up the plywood ceiling. The fire was well along before the smoke drew his attention. In

panic, he came down and rushed to find an extinguisher, but the fire got away from him.

The regular fire squad was off duty, but a call for help brought men from the tool room. One of them brought a pressurized extinguisher, but in his excitement, activated it on his way down, and arrived with the extinguisher empty. By now, the powder in the loading room had burned, really turning on the blaze. The Marikina Fire Department arrived promptly, and started containing the fire. In the meantime, the fire had spread to the loaded ammunition. All three loading rooms burned, but the rest of the plant was untouched, except for smoke and some water. The roof, aluminum, over the fire area, except for the hole where the hottest part of the blaze had burned through, looked like a large sized lace curtain. The 5.56 mm ammunition, when it popped, either blew the bullet or the case upwards. The flying objects would go through one thickness of the hot aluminum, but not two where the sheets overlapped.

The fire covered about 4,000 sq. ft. of floor space. Monday the clean-up started. The loading machines were torn down, cleaned, reassembled, and fitted with new motors. They were back in operation in about 5 days. The factory was back in full operation in 10 days, open to the skies. It was the dry season, and a lack of roof was no hindrance. The roof came later.

But for carelessness, and a broken rule, there wouldn't have been a fire. There was no explosion, and no one was hurt. The same sort of fire could have happened in any factory handling flammable materials. Which goes to show that an ammunition plant isn't all that dangerous, if the real explosive dangers are guarded against.

CHAPTER XV WORKING IN FOREIGN LANDS

Remington, Winchester, and Cascade Cartridge Co. have all set up plants in countries outside the U.S. Not being privy to their various corporate balance sheets, I can't say how financially successful they are. I am sure, however, that each had somewhat the same problems in setting up their foreign operations.

Mexico

Cascade Cartridge had to try twice before getting its Mexican plant off the ground. The first try didn't make it because the project lacked a key individual, a Mexican national with enough technical background to understand the demands of the process, and enough administrative ability to organize and run the business. On the second try, the company picked a winner, Ricardo Ortiz, English speaking, a chemical engineer, a good administrator, and a good politician, with considerable skill in picking people thrown in. Ricardo paved the way almost literally for the plant by getting the governor of the state of San Luis Potosi to build a road into the land that the governor had arranged for the company to obtain, and to have a deep well drilled for the water supply. This speaks well of the aforementioned political ability.

At an earlier time, Olin had considered putting a plant in Mexico, but the project didn't get past the board of directors. I had wanted to run the Mexican plant, but after my later experience in Mexico and still later in the Philippines, I'm not really unhappy that I never had the chance. Olin's original Mexican plan hadn't contemplated the key national.

A foreigner, like myself, not fluent in the local language, not well steeped in the mores of another people, and a long flight from the home office, with communication a little less than instant, has two strikes against him and only a hope that he can maybe foul the next curve ball. I say this now, but, at that time, I would have tackled the Mexican job with enthusiasm.

It might be easier to start up a foreign operation working with a large company, which would be able to provide broader technical service and more financial backing. Cascade Cartridge, at the time it went to Mexico, was not a large company, had need of its engineers and tool makers at home, and didn't have a large reserve of capital to risk.

The day after I landed in Lewiston, Idaho to join Cascade, Dick Speer, the president, called from San Luis Potosi, Mexico. I was to come there as soon as possible. Getting there involved a visit to the Mexican Consulate in San Francisco for a working visa, a flight to Mexico City, and a search in halting Spanish for transportation to San Luis Potosi. I had the thoroughly enjoyable experience of taking a nine-hour ride in a third-class bus filled to overflowing with people, chickens, school children, a pig or two, one small goat, numerous vegetables and bundles of all sorts. Stops were frequent, including one where the bus had to back more than a mile into one small village because there was no place in the village for the bus to turn around. San Luis Potosi turned out to be a far different place from the border towns I had visited during the war. Severely colonial, the city streets were paved with stone, the public square tiled, and complete with bandstand. Buildings were old, but well maintained. It was a safe city to walk around in day or night. Friendly people. Stores well stocked with current and traditional merchandise. The elevation is 6,200 feet; the climate mild to hot in summer, cold indoors in the winter, but warm in the sun.

The ride provided an introduction to Mexico, that I never would have gotten by flying from airport to airport. Though it didn't seem so, then, it was well worth the discomfort.

The area is in the high plateau which runs north to south in Central Mexico. The plant was about three miles outside of town. Only the goats fed well on the desert vegetation, and they had to work at it.

For miles up and down the plain, small dust devils spun, moving with the prevailing breeze. These baby tornadoes looked innocent, but weren't. Most missed the plant in passing, but one day one didn't. Off came doors and pieces of roof, papers flew in all directions, and the wind-driven dust blew into every nook, cranny, hole, container, and every machine with furious determination. It took about a week to clean up. Dust and ammunition don't make good partners. The dust scratches the dies and scratches the shells. I now respect the Mexican variety of dust devil.

After my settling in, we went to work on the machinery, which was already in place. Starting

on the rimfire case line, we soon found the first trouble, and thereby learned a lesson: Never ship a machine or tool from the home plant that hasn't been tested and found working to perfection. Nothing ever works quite as well away from home as it does at home, at least not to start with.

The Mexican plant machinery had been converted from good surplus military ammunition machinery at Lewiston, but hadn't been debugged before shipment. This was partly because CCI at Lewiston hadn't gone very far in producing rimfire ammunition either, and hadn't had much ammunition experience beyond making primers.

To start the drawn cases didn't head well. We modified the draw punches and dies. Then, the header gave us headaches. A converted .50 caliber header, it was heavy enough to head three shells at a time, a light job on a .22 rimfire case. The machine had enough slack in its various parts that, if the right hand punch was set up first, it went out of gauge as the left punch was adjusted. Adjusting the middle punch threw both the right and the left out of gauge.

It took a couple of days for Clarence, the American machinist with us, and me to get the hang of things. Then it took a week's training to teach the local adjuster how to set up the header.

Finally, we made good cases, then started on priming. No problems with the chemistry and the mix, the chemist had been trained at Lewiston and knew her job. Porfilio and Joanna, the charger and spinner operators, had to learn from scratch. They picked up the fundamentals quickly, and were left to carry on limited production, while the bullet operators were being trained.

Not many bugs in the bullet department, so on to loading. Here was a mess. There was a mix-up in loading plates shipped from Lewiston, old and new plates and experimental plates thrown together, and none fit the drawings. Finally, the loading problem was sorted out. Powder charging was simple and the operator assured us he understood the need for uniformity.

Next came the crimper, again not thoroughly tested at Lewiston. It showed a distressing tendency to roll the bullets out of their cases, rather than crimping them in place. The design by CCI was quite different from the crimpers that I was familiar with, but with some reworking of the tooling, it soon fell into line. Now all the ducks were in a row.

The whistle blew and production started. The crew blanked, cupped, annealed and washed, drew, trimmed, headed, primed, made bullets and loaded. Caution prevailed, only a few hundred rounds the first day. The second day, 30,000. Quality was poor. There were misfires, some pressures were too high, some too low, and velocities were varying accordingly. Bullet pulls were far from uniform. Accuracy couldn't be bragged about.

All these things were, to a degree, to be expected. People still didn't fully understand what they needed to do, and how carefully they had to follow routine.

The general elation over starting up was dampened when all production was stopped, and the production people called together and lectured about sticking to procedures and instructions to the letter. All joined in a procession to a burial pit.

A solemn Porfilio rolled up with the entire 30,000 rounds dumped in a wheelbarrow. The ammunition, which looked like a small fortune to these people, was tipped into the pit, annointed with oil and kerosene to make sure it wouldn't be worth digging up, and buried. A final closing lecture on the need for quality ended the day. Hoping for a better day tomorrow, the crew went home.

The next day was better, and by the end of the second month, production was moving up, and quality was good. I went back to Idaho to get busy on .22 rimfire production there. But, all did not end well.

On my next trip to Mexico two months later, there had been some backsliding. Not unusual, not all people remember or believe all they've been taught. Making good ammunition requires constant checking on people to make sure that things are being done exactly as specified. An occasional visit from the home office isn't enough to sustain a new operation.

There was not enough technical expertise in Mexico to cope with the day-to-day glitches that pop up in ammunition making at the start. The Mexican manager, trained at Lewiston and generally competent, had not had long experience in ammunition making and had too many things to cover by himself. It was necessary to back him up with a full-time technical assistant, which was done. The company sent down Ron King, a good toolmaker, very knowledgeable in ammunition making and with a fortunate gift of learning the language quickly. From then on, progress continued steadily.

There were lessons of value in the Mexican experience:

1. When setting up a new plant in a new and developing country, particular attention must be paid to providing completely reliable, fully operational equipment. The simpler the machines, the better. In setting up a joint venture, where part of the assets consist of machinery to be furnished by the parent company, don't be tempted to overprice excess obsolete machines and foist them on the new venture, hoping that distance will make things work better. This is asking for trouble—a developing country cannot cope with trouble shooting, debugging, machinery rebuilding, plus starting up the manufacture of a new product. There

aren't many spots where one can instantly find all the small items needed for starting up. Mexico City was the closest spot we could hope to find any special tools, tool steel, bearings and similar items. San Luis Potosi couldn't furnish much beyond standard hardware store stocks.

Certainly, good machines, obsolete in developed economies because of labor costs, have a rightful place in a developing country with low labor costs, providing that the machine can do the job. CCI's machinery sent to Mexico was excess in the U.S., but was basically sound, needing only debugging, which, unfortunately, had not been completed.

2. Continuing, on-the-spot technical assistance, always available, must be provided until production is well established and stable. As much as possible, training of foreign personnel should also be provided in the home plant. Personnel should be trained in pairs, so that each individual can back up the other, mutually bolstering their strength in imposing necessary methods and procedures. CCI trained the chemist and the general manager, but probably should have brought one or two more people up to Idaho for training.

3. It is preferable to have the foreign plant headed by a national or at least by a long term resident of the foreign country with good knowledge of the language, customs, and methods of doing business. A foreigner, if he has to do it all, has too much to learn about personnel, local conditions, politics and other things to do his job well in bringing the technical side into line.

Actually, the CCI Mexican operation probably went as smoothly as could normally be expected. Time elapsed from start of construction to limited production was a little over a year. A principal competitor, setting up in Mexico in the same line of business, took quite a bit longer, for reasons that I have never determined. Maybe their plant was a little more ambitious.

The Philippines

In 1965, I was called to the Philippines as a consultant, by Squires Bingham Manufacturing Company. There was a problem with rimfire ammunition production, which had been started the year before. High pressures and burst heads. This was not starting up a new plant; it was adding a new and different product—ammunition.

The company had been in the firearms business for several years, having sold its first rifle in 1954. There was also manufacture of Yale locks, Stanley hardware, as well as a small air conditioning line. As a result, there was a good solid base of engineering ability, an established tool room, and general familiarity with metal working. The principals of the company were hunters and shooters, as well as businessmen. Ammunition equipment had been purchased as a complete line for making .22 L.R. from Manurhin. Knowledge of priming chemicals and mix and charging and spinning had been generously furnished through the good offices of Mr. Charles Horn of Federal Cartridge Company. The chemist had been trained at Federal.

It didn't take very long to solve the basic problem. The company had ordered by mistake a powder that was far too fast burning for .22 Long Rifle ammunition, particularly the high velocity round. Actually, the powder was best suited for .22 Shorts.

Pending the arrival of a slower powder suitable for the .22 Long Rifle, we did considerable work with the powder on hand, finding that by very, very careful control of powder charges and keeping pressures slightly above normal but still within safe limits, we could load essentially at standard velocity. This let the company produce a round that had limited sale in the local market, but was certainly not fit for export.

In order to control the accuracy of powder charging to the very narrow limits necessary, we made modifications to the powder charging turret on the Manurhin loading machine, adding a small interior stirrer, which kept the powder in a state of agitation as it dropped into the loading chamber prior to being dropped into the shell case.

There were other problems involved in the ammunition manufacture, which were holding back production. The draw press was rather complicated in that there were three dies involved. The case was drawn on the first die, pushed out, transferred, drawn on the second die, pushed out and transferred to the third die, where it passed all the way through and was ejected into the work basket. The transfer mechanism was somewhat complicated, being a ratchet affair, and the machine had considerable downtime.

The trimmer was of the type which accepted the drawn shell into a chuck, trimmed it, and then pushed it back out where it fell into the same work section as the trimmings themselves. This necessitated a rather laborious separation of trim and finished work. Federal Cartridge had a much better machine, of which Squires had a prototype, that allowed the work to be pushed on through the spindle from the chuck. The trimmed shell was ejected at the far end of the spindle, clean and not mixed in with the scrap. One of the first steps was to start duplication of this machine, whose accuracy was excellent.

After a pleasant two and a half months, I returned to the States, again having enjoyed my stay and the people of the country. One of the fortunate things in the Philippines versus Mexico is a much wider use of English. No matter where one goes, somebody speaks English. There is very little problem in communication in the simpler things. In the technical field, communication with the average worker is a little more difficult. Engineering edu-

cation is mostly conducted in English. The problem of handling technical things through an English-speaking engineer and getting the information over to the workman on the machine, who may or may not understand English completely, is much easier.

I came back to the Philippines again in 1967 to work with the company on a problem involving firearms. After a two-month stay, I went back to the States, but late that year I agreed with Bolo Tuason, the president, to come back to the Philippines on a full-time basis, which I did beginning in 1968.

So far as people are concerned, there is very little difference in the basic attitudes and feelings of the Mexicans versus the Filipinos. This is partly because people are somewhat the same the world over, and partly because of the earlier 400 year-long Spanish influence, which was exerted on both countries.

Both Filipinos and Mexicans are hard working, diligent, but display a certain independence of spirit in getting the job done. They insist in a quiet way on a certain amount of their own initiative rather than on strict adherence to set routines. This makes for problems sometimes in ammunition making, where the process must be carried out without deviation from an established production plan. This is probably the biggest problem that one has. The general attitude seems to be very well expressed in the famous Sinatra song "I Did It My Way." This might even be somewhat of a national anthem.

Not only with Squires Bingham, but in almost every company making consumer products here, there is a strong feeling that if it's made at home it can't be very good. Most products are dismissed with a short comment, "local," complete with shrug. The customer then turns to an imported item if it is available, even at a much higher price. So it was with Squires Bingham arms and ammunition for a time.

For much of its history, Squires Bingham had been a mercantile company. After the end of World War II, the tremendous demand for guns and ammunition led the company into manufacture of rifles, first deliveries being made in 1954. In 1968 there were four company owned stores in Manila, all selling imported arms and ammunition as well as the company's own. Imports led sales by a very wide margin, "local" being scorned unless the buyer could afford nothing else. Even though the store managers had cut prices on the local products to a fraction of the imported prices for equivalent firearms, sales were poor.

In an effort to improve the profit picture, thought was being given to the export market. A trial marketing of the company's semi-automatic .22 rifle in the United States showed promise. Down in Australia, there was interest in both .22 rifles and ammunition, and shipments were well accepted, particularly after the rifles had been restyled in minor ways.

Even with the prospect of export, the profit picture was not good. So, over the strong opposition of the store managers, who swore a price increase would kill sales altogether, prices of the company's rifles were raised sharply, almost double. Local response was almost immediate. With the offered price still almost a third less than that of imported firearms, gun sales jumped. Demand went far beyond supply overnight. Comments on improved quality began coming in, even though there hadn't been changes in the basic guns.

The simple answer was that the product had been priced so far below imported competition that people couldn't believe that the guns were truly a bargain. Quality couldn't be that cheap. Raising the priced raised the image of quality.

Ammunition, with a shortage of imported cartridges, also picked up sales. There wasn't any other choice. At the same time, .22 ammunition shipments were being made to Australia. One such shipment, already marked for Australia on the cases, was diverted to the stores, who were out of stock. Noting it was of "export quality" the customers snapped it up, and demanded more of the same, because they said the quality was so much better—which it wasn't, export and local both came off the same machine. Putting a premium price on the export-marked boxes only whetted desire. If the Australians wanted it, it must be good enough to buy. Sales continued to soar.

So began an expansion of the manufacturing facilities on a fairly continuous basis, except for a short lull in 1972, when martial law came in. Export soon took up the slack, and capacity again had to be doubled, and later doubled again, and again.

The key was realistic pricing of a good product. Without the advantage of a long and well established name, some price concessions need to be made for equivalent products, but such concessions must still leave fair prices. In Australia, pricing has been fair to both the maker and seller with market acceptance excellent. Half of all the .22 rimfire, semi-automatic rifles now sold in Australia come from one source—the Philippines.

From a financial standpoint, the company, now called Arms Corporation of the Philippines, being small and in a very competitive market, has been in no position to embark on an expansion of plant facilities by purchasing entirely new equipment. New sophisticated machinery as well, until recently, would not have fit in with local abilities from the standpoint of maintenance. In 1968, competent repair people who could handle electronic circuitry and machine control were very scarce in the Philippines. One had to bring in an expert from outside. The answer seemed to be the use of simple,

general purpose machines, generally one operator per machine and one operation per machine. In the States, this would have priced the company out of the market because of the cost of labor. In the Philippines, where the wage in 1968 was equivalent to about one U.S. dollar per day, the additional people were possible.

The company had the ability to rebuild machines, to design entire new machines when necessary, and to build these machines. The ammunition plate loading line, trimmers, spinners, and various feeders were designed or copied and fabricated by the company's own workmen. One of the first things done in 1968 was to convert the rimfire draw press with its troublesome three draws into a single draw press with two punches, each producing a finished drawn shell per revolution. This doubled the capacity of the machine as far as the number per revolution was concerned, and also reduced the downtime from some 50% to less than 5%.

Along with increasing its .22 production, the company also went into manufacture of .22 Magnum ammunition and in 1970 prepared to branch into centerfire ammunition. Arrangements were made for the company to purchase a .30 Carbine ammunition line from the defunct Leon Beaux plant in Milan, Italy. This machinery was shipped to Manila and was on the floor when martial law was declared in 1972. After negotiating a contract with the government, the machinery was converted to 5.56 mm military ammunition production. Also, a portion of the machines were converted to making other calibers, including .30 Carbine as it was already tooled up, and .38 Spl. This broadened the company's ammunition capabilities by a considerable degree.

The Leon Beaux machinery was fairly old, not all in the most perfect condition, but had the advantage of being simple, fairly easy to tool up and, above all, was cheap. The company paid $40,000 for some 42 machines, added about another $15,000 in transportation, and had them here in the plant.

The 5.56 mm line called for the purchase of a few more used machines, which were gotten from the States. Some additional machinery was made from the company's own designs. Had all new equipment been purchased, the cost would have been several million dollars, judging by recent quotations on new ammunition lines, particularly for the 5.56.

It would seem today, for a small market, that the cost of ammunition machinery offered is far beyond the ability of a small company to buy out of earnings. Squires Bingham was fortunate in that, at the time it started on the expansion program, used machinery was available in quantity, and that the company was able to make use of it.

Some final comments on doing business abroad may be in order. A developing country, such as the Philippines, has a great many opportunities offered in the way of joint ventures, transfers of technology, licensing arrangements, and the like.

Many companies aiming to do business with manufacturing companies in the Philippines, as elsewhere, have had negotiators who felt compelled to drive a hard bargain to impress the home board of directors and management. Zeal is fine, but it can be overdone. Unfortunately, some such bargainings, made too dear, become onerous to one or both parties. Altered circumstances, poor market studies, inadequate financial arrangements, unusable technology, misunderstandings, and plain greed lead to failures.

Grabbing too large a percentage of gross sales as a reward for partnership, without provision for lean days or losses, together with restrictions on other markets, are the commonest primrose paths down which foreign partners lead themselves, and the deals turn sour. Contracts must provide for renegotiations and relief if both sides hope to get along.

Of the several agreements Squires Bingham entered into, none turned out equally fair to both sides. Technology wasn't adequate and wasn't worth the price. There were too many middlemen between manufacture and customers. Quality standards weren't clear. Some designs were not suitable for local manufacture. Too much money came off the top. An oversized production facility with sales restricted to local. These are the things that Squires and other companies have at one time or another been bargained into through lack of experience.

Special tribute, however, must be paid to Mr. Charles Horn, the late president of Federal Cartridge Company, who volunteered the extensive help of his company in getting Squires Bingham started making ammunition, without cost to Squires. Technical service, training of key personnel, and help of all sorts was freely offered. Such rare philanthropy in this day and age merits special recognition.

Similar recognition must be given and tribute paid to another very worthwhile philanthropic organization, the Canadian Executive Service Overseas. CESO provided the services of four retired technical and executive people to help in starting up the centerfire cartridge program. The direct on-the-spot assistance of Ken Steward, Dave Atkins and Harris Sherwood, all from Canadian Industries Ltd., and Gordy Britton was invaluable.

CHAPTER XVI
TIDYING UP

Ammunition can't be made without creating a certain amount of waste, a good bit of which is downright pollution, more and more a naughty word. Once the cartridge is made, there comes a time as in baking a cake, to tidy up the kitchen.

Waste disposal is a real item of expense, hence this chapter.

To begin with, there is no practical way that all wastes can be combined and treated together. As much as possible each waste, waste water and rinse water has to be treated at its source.

Plant safety demands that explosive wastes be destroyed, swept-up powder burned, strong acids be disposed of and sumps be cleaned.

There comes a secondary problem, as in the case of lead styphnate—what to do with the by-products of the explosives' destruction. The hazard is reduced but an ultimate problem remains.

For several reasons—public sentiment, common sense, and legal requirements, strong acids can't simply be dumped in the sewer.

The wash waters from TNR and lead styphnate preparation, and the wastes from the explosive sumps are highly colored. To most any observer the brilliant yellow color spells pollution.

Other pollutants, lead, copper, zinc, nickel, barium, plating salts containing cyanide, and resorcin must be considered in the effluents from the ammunition plant. Resorcin is one of the phenols, a most difficult pollutant to destroy in diluted waste water.

More and more, cities, states, and nations are setting up effluent standards for industrial plants. Here in Manila the National Pollution Control Commission has established the following limits not to be exceeded by any plant discharing waste water into any estero, stream, or lake: (the limits are expressed as milligrams per liter of water):

Barium	2.	Nickel	.5
Copper	1.	Cyanide	.1
Lead	1.	Phenols	.05
Chromium	.05	Detergents	1.

pH limits are 6 to 8.5, Color limit is 100 platinum-cobalt units

These limits are higher than those permitted in drinking water. Presumably the waste will be further diluted in the main stream.

It is beyond the scope of this chapter to describe a complete waste disposal system. An overall system is best designed by professionals. The following notes are intended only as a rough guide.

Editor's Note: The pollution limits, specified here, are current as of 1988 and apply only to the Republic of the Philippines. In the United States local jurisdictions, acting in accordance with either state or federal government guidelines (or both) license or permit the discharge of waste into water supplies. Permits in this instance are granted on a case by case basis and allowable levels vary according to many factors, among them toxicity of the particular effluent, volume of water flow, population, etc.

Pickling Acids and Nitrating Acids

Since the flow of these is intermittant they should be collected, then metered into a more steady flow of rinse waters. Neutralization is with caustic, NaOH solution. The essential equipment consists of a series of at least 3 tanks sized to give a total retention time of about 1 hour. Sizing will of course depend on the average flow of water. The first tank, equipped with a stirrer, has a pH probe operating a solenoid valve which admits caustic solution to the tank according to demand. A second tank, also with stirrer, allows more time for stabilization of the reactions. More caustic may be added here by a second pH probe located in the outflow of the third tank.

The third tank has baffles to channel the flow of water which prevents short-circuiting flow from inlet to outlet.

A pickling effluent, which will contain copper and zinc, may be routed to copper and zinc removal. A nitrating acid effluent will be colored, contains TNR, and needs a different treatment.

The neutralizing tanks may be made of concrete, epoxy painted.

This neutralizing system will satisfy most pollution control requirements.

Lead Styphnate

Lead styphnate is commonly destroyed in small quantities by treatment with strong NaOH solution in the presence of acetic acid. This treatment transforms the lead styphnate to more soluble, and non-explosive sodium styphnate. In hot solution the sodium styphnate will remain in solution. When cool the styphnate will settle out as a gelatinous mass which may be collected and burned. This will get rid of most of the troublesome resorcinol. The lead will tend to remain in solution as the acetate.

An effective method of lead removal is described in the Journal of the Water Pollution Control Federation (March 1982 issue). The method in-

volves creating a colloidal floc of ferric hydroxide in the effluent, adding a sodium lauryl sulfate surfactant, and blowing air through the liquid as it passes through a tower. The result is a foam containing the floc and the lead which the floc has adsorbed (with emphasis on *ad*sorbed). Breaking down the foam leaves a sludge containing the lead. It is said that this method, when properly controlled, will reduce lead to .1 parts per million in the effluent.

The approved procedure for scrapping overly sensitive batches of lead styphnate, where safety overrides other considerations, was given in Chapter V, The Primer.

Cleaning of sumps where lead styphnate or priming mix have accumulated follows somewhat the same procedure. The sump is carefully bailed out so as not to disturb the settled material. Boiling water is then poured into the sump and a portable mixer installed, making sure the mixer blades do not contact the solids. Caustic solution consisting of 4 kg. NaOH to 8 liters of water, at the rate of 1 liter for each estimated kg. of explosive is then added. After 2 or 3 minutes of mixing, add about 1 liter of glacial acetic acid (56%), for each liter of caustic added. A dark, but clear solution should result. This solution may then be treated to get rid of sodium styphnate, most of which will settle out on cooling, followed by removal of lead from the clear liquid.

Tetracene

Hot water and NaOH, treatment as for lead styphnate, will destroy tetracene.

Barium

Barium nitrate is, as noted in the chapter on Primers, a principle ingredient of priming mixes. Its solubility is about 100 grams per liter of water at normal temperatures. Obviously any waste water which has been in contact with priming will have more than the allowable amount of barium in it. The permissible amount of barium being .002 gram per liter, equivalent to .004 gram of barium nitrate, a liter of a saturated solution of the nitrate would have to be diluted 25000 times to pass.

In this case, advantage can be taken of the relative insolubility of one of two barium salts: the carbonate at .022 grams per liter, and the sulfate at .0022 grams/liter.

Simple treatment of the waste water with sulfuric acid will precipitate almost all of the barium, leaving a saturated solution of barium sulfate at .0022 grams/liter, needing no further dilution.

Similarly, treatment with sodium carbonate would leave a residual barium in the water needing only a 10 to 1 dilution.

Residue in Sumps

With the removal of barium by dissolving it out, and the lead styphnate by "killing" its explosive nature, the remaining residue in the sump, including the gelatinous sodium styphnate should be removed and burned.

Again a warning on working in sumps. The most dangerous spot in the priming area is the sump. The settled-out material may have had crystal growth making it more sensitive. The dense lead styphnate settles into a hard cake much more apt to explode when disturbed. Better to stick a finger in a tiger's eye than to poke at a dry sump. Cleaning at two week intervals is none too often.

Color

After the foregoing treatments there still remains the matter of color in the waste waters, including those from the nitrating acid neutralization, rinses, and flushing of sumps. The color is from the small amounts of TNR and TNR salts dissolved in the water. Chlorination might seem to be an answer, as it will remove the color. However chlorinated phenols are especially undesirable because of the strong taste they leave in drinking water, even in extremely small concentrations. There is another reason also; The reaction of chlorine, as gas, as sodium hypochlorite, or calcium hypochlorite, with the styphnates produces a gas which is strongly lacrimatory, a tear gas if you will.

The best answer seems to take advantage of the biodegradability of common sewage in a system of the aerobic type to oxidize the phenols. Being so-called "refractory organics", meaning that they are slower and more difficult to oxidize, these wastes normally wouldn't be simply mixed in with other sewage, but handled separately. The surest method is by ozonation, an expensive process.

An alternative process, more expensive, is to adsorb the phenols on activated carbon.

The Metallic Ions (copper, barium, chromium, nickel, zinc)

Out in Butte, Mont. the water pumped out of the area's famed copper mines is acidic and contains much dissolved copper. The answer there is to run all the water from the mines through huge beds of rusty tin cans. By ion exchange the copper is deposited on the can surface while the iron goes into solution. The black copper residue has value.

Pickling waters, rinses, and neutralized acids may be treated similarly. The combined effluent can be allowed to flow slowly through beds of steel chips or turnings.

Barium as discussed earlier is handled separately.

The other metallic ions may be removed by an

ion exchange process using suitable ion exchange resins operating on an acid cycle. The resins exchange hydrogen ions for the metallic ions, forming acids from the former salts, and leaving the collected ions on the resins. The resins are regenerated by an acid treatment and reused. This leaves the regenerating solution, now containing the metallic ions in a concentrated form, to be disposed of. Evaporation seems to be the ultimate answer to that.

The resins could simply be thrown away and replaced, but they are expensive. Here is another spot where professional advice is recommended.

Cyanide

Plating rinses containing cyanide are best treated with chlorine, which destroys the CN ion. Treatment is preferable right at plating before the wastes join any other effluent. Metallic ions, such as copper and nickel, if in objectionable quantity may be treated as above.

Detergents

All detergents used in washing ammunition components should be biodegradable. In many places any other type is illegal. Being degradable, the detergents are destroyed as they pass through the plant's sewage disposal system.

Because of the diversity of materials, wastes, and processes involved, setting up a comprehensive plan to handle all waste is a far from simple job. The basics are (1) keep all effluents needing treatment as small in volume as is practical, (2) keep all effluents separate until treated.

CHAPTER XVII
A FEW FINAL THOUGHTS

Here are a few random thoughts on the ammunition business in general. Where is it headed? What new can be expected? The foregoing chapters have dealt with usual processes, essentially in their fundamentals. Lately machines have been developed to combine these processes, and produce loaded ammunition from stock, non-stop. But, the processes themselves are not much changed. A case is still drawn from a cup, and the cup is made from strip or rod. One can look forward to various rearrangements in the composition of these large scale machines, but great changes in methods are unlikely.

Highly satisfactory shotshell cases have been made by the impact extrusion of plastic, and by other treatments of plastic, such as extruded tubes. Metal shotshell cases are nothing new. Paper tubes are almost a thing of the past, except for a few made on long-existing machinery that can take advantage of a cost saving in paper over plastic. Shotshell cases are assembled, headed, primed, and can be loaded at the rate of several hundred per minute on one large machine. The steps involved are still basic. No great change can be foreseen in this area so far as ammunition for existing guns is concerned.

One thing to remember about these large composite machines is that each step provides an opportunity for something to go wrong. If something does go wrong the whole machine stops automatically. A large capital investment sits idle until the machine is fixed and restarted. Not so with a line composed of single machines, where one machine failure doesn't stop production for long, unless there is no floor inventory between operations. So far as sporting ammunition is concerned, there is still a place for single, simple machines for short runs. Only the major companies, and government-owned plants producing military cartridges in large quantities can begin to justify the capital expenditure necessary to take advantage of large scale production of individual centerfire calibers.

The present outlook seems to be business as usual, with a certain amount of machine replacement and upgrading in the commercial field, volume being dependent on the market situation, but shrinking. More about the market, later.

Eleyprime, mentioned in an earlier chapter, may well be adopted for priming as a safer, cheaper, faster, and more direct way to prime rimfire cases, as well as centerfire and shotshell primers. There doesn't seem to be much to be gained in research on new primer chemicals, although some possibilities may be there. The non-corrosive primer field has been exhaustively studied and researched for more than 60 years.

With the many, many millions of sporting and military firearms already in use, conventional ammunition is not likely to change much in configuration, except for possible changes in bullet design.

Even though today's bullets provide a great variety of designs for more or less specific purposes, some further new designs will probably come along to satisfy the continued public demand for something new and different. This is part of what keeps competition alive in ammunition sales.

Cases will continue to be made of brass, with some aluminum creeping in. Steel is of limited use. No other metal meets the requirements for the case. The remaining possibility for the case is plastic material. The perfect plastic for a rifle case hasn't yet appeared. Look to the military for new developments in weapons, calling for cartridges of possible new design. Caseless cartridges have already undergone considerable study.

Propellants now in use are the results of more than 90 years of development. So far as nitrocellulose and nitrogylcerine are concerned, they have probably been exploited to a near maximum. Again, look to the military for exotic new propellants.

In the ballistic lab the usual tests will prevail. It is of course feasible to mechanize ammunition testing to a certain extent where large quantities of a single caliber are being produced on a high speed production line. Provision may be made for sampling at a given interval. The cartridges withdrawn may be automatically fed to a piezo-electric type pressure barrel and automatically fired, with pressure, velocity, and barrel and ignition time being recorded automatically. The apparatus would of course have limiting provisions that would stop the process, or at least ring a bell when any control limits are exceeded. However, for short runs of less popular calibers, the current procedures are probably the most economical, and certainly the most flexible.

Function firing isn't so simple. The variety of firearms that use a given caliber may be large. The cartridge has to work well in each model. Further there are interactions between individual guns and the cartridge which need the ballistician's special knowledge to sort out.

Theoretically, primers could be drop tested on a

continuous basis. But it would be quite complicated considering the changes in run-down drop heights from no fire to all fire, plus the need for drying the primers before testing, since the normal practice is to charge wet. Then there is the effect in the cartridge of variance in head hardness and primer pocket size and seating depth to stick with the present practice.

Shotshell patterns may be measured photo-electrically, saving laborious pellet hole counting. Clean holes through the target paper, a strong backlight shining through the holes and a photo-electric cell picking up the light shining through, would do the job. Accuracy results have long been measured by TV from the firing point by scaling the TV image. As a refinement a computer could be used to analyze and record hit location, and to automatically compute extreme spread, extreme horizontals and verticals, mean radius, and even figure of merit.

The above tests are those most frequently performed. Less frequent tests will likely continue to be handled as at present.

The sporting ammunition is faced with a slowly shrinking market. Several factors are at work, not the least of which are changing times and attitudes. When I was a boy at the age when boys owned B·B guns I would about as soon have appeared in public without pants as to be seen without my trusty Benjamin air rifle. Sparrows (NRA's admonition notwithstanding) were considered a nuisance, good only for salvaging used oats and chirping, and were therefore legitimate targets. Nobody thought it a terrible thing that I should be carrying a B·B gun, so long as I didn't carry it to church or school. Nowadays, at least in most of our urban areas, a boy in public with a B·B gun would prompt a dozen calls by nervous mothers to the local police. Not that I'm against motherhood, but many mothers have been misguided, so far as the sinfulness of guns is concerned.

In the case of my own children, who grew up in a house full of guns, and with ammunition readily available, we never had any problem with our own children. The minor problem we had was the neighbors' children, full of curiosity about guns, whose mothers wouldn't let them have or touch guns. Our children kept order. Their friends could look, but not touch, unless I was present. There seems to be a lessening of interest in target shooting. Neither of my children, who were taught to shoot at an early age, and who went with me to quite a few matches, ever attempted to shoot in competition. Part of the reason at least was the lack of a shooting program in the school—this is the Connecticut River Valley with all its gun companies. TV pretty much took care of any spare time. Not to be overlooked in market effects is the gradual loss of hunting and shooting areas. As it becomes more difficult and more costly to find a place to either hunt or shoot, interest dies out. As a result both gun and ammunition markets are headed for gradual shrinkage, the ammunition market maybe not as fast as the gun market. With the many millions of guns now in shooters' hands, some guns are bound to be shot occasionally.

The days of carefree plinking, when a box of .22 Shorts cost less than fifteen cents and Long Rifles were a quarter, and there was no lack of places to plink, are no longer with us. .22 Shorts used to far outsell .22 Long Rifle. The shooting gallery, a favorite at amusement parks and arcades have been almost completely replaced by video games stands (which, by the way, are themselves banned here in the Philippines). The restrictive Federal laws on ammunition sales, even though recently somewhat relaxed, have had their effect, particularly on the teenagers, who have simply found other things to do; some of them not altogether praiseworthy. I'm sure I got a lot of enjoyment, and a lot more physical benefit, out of coming home from school, dropping my books, changing clothes, and, in the winter, putting on my skis, and heading for the great snowy outdoors, shotgun in hand. Following rabbit tracks and shooting at homeward bound passing crows was a lot more fun than any boy ever got out of 2 hours of TV.

The military market will have its ups and downs, depending on national budgets and real or imagined threats of war or subversion.

While the ammunition business may be slowly shrinking, it will be with us as long as there is some hunting and target shooting, and as long as there are wars. It may not be in the cards for a newcomer to enter the market successfully on a large scale. Competition from the four principal U.S. makers, high capital investment, and the problems of establishing distribution, would make that row a rough one to hoe. There is one area where the small producer has some chance. As certain calibers gradually lose popularity and sales fall off, their manufacture is eventually stopped. Continued manufacture by one of the major companies doesn't quite fit in with their pursuit of the almighty dollar. There is still some demand, as anquished outcries from gun owners will testify. Here, a small producer, with a line of single purpose, simple ammunition machinery, plus a good tool room, can fill a gap at some profit. Granted, sales will continue to drop, and at some point all further production stops and the cartridge fades into oblivion. In the meantime, there have been several years of small scale production.

There are also special police types of pistol and revolver and riot control cartridges to consider.

The possibility of private brands shouldn't be overlooked either. The small operator who can keep his overhead low, his capital requirements

within reason, and can let one of the chains handle his distribution, has some chance with private brands. There is a worldwide export market which is quite competitive but can be attacked.

There are however some pitfalls. Relying on a single customer for private brand distribution is always risky. Also product liability insurance costs are high, and the risk of damage suits with huge awards can't be overlooked. Both manufacturer and the distributor get sued. Still there are opportunities although, as can be seen, they are not unlimited.

And now to wind things up. At the beginning I tried to point out that the basic idea behind the book was to provide a modicum of knowledge of the ammunition business, which to me had been a pleasant workplace. It was not intended to encourage competition, or to discourage it.

I hope the reader enjoys reading what I have written as much as I enjoyed writing it!